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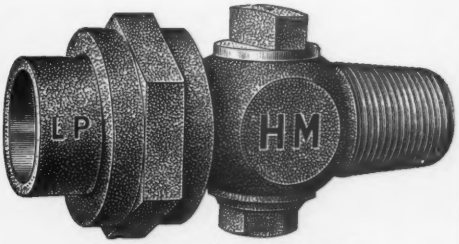

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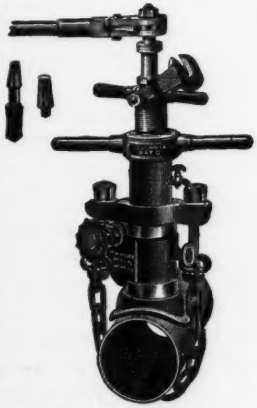

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THE BACTERIOLOGICAL ANALYSIS OF WATER AND ITS INTERPRETATION.

BY CHARLES-EDWARD AMORY WINSLOW, INSTRUCTOR IN BIOLOGY, MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

[*Presented September 18, 1901.*]

INTRODUCTION.

The determination of the exact number of bacteria present in water was for a long time a difficult problem, and the greatest advance ever made in bacteriological technique was the method of solid cultures, or rather of cultures either solid or liquid at will, suggested by Robert Koch in 1881, which finally solved this difficulty. If a measured quantity of water be mixed with a portion of melted nutrient gelatine and poured out on a cool glass plate, the medium solidifies and the contained germs are imprisoned and separated from each other. Each bacterium multiplies rapidly by division, producing finally a visible colony; and by counting these colonies the number of individual germs in the original sample may be determined. Very soon after its introduction this method was extensively applied to the sanitary examination of water, and it was at first assumed that the number of bacteria was a rather direct measure of sewage pollution. This too exalted idea of the importance of the bacterial count was followed by a tendency to discredit it altogether, and this, in the present time, by a wiser confidence born of more exact knowledge of the real significance of the test.

Pasteur's work established not only the relation of bacteria to disease, but of specific bacteria to individual diseases. It seemed obvious, therefore, that the best possible evidence of the contamination of water would be the isolation of such specific germs,— in particular of the germ of typhoid fever, the principal water-borne

disease. At first the attempt to isolate these forms appeared to be successful; both the typhoid bacillus and the spirillum of Asiatic cholera were reported as found in many water samples. Further study made the problem much less simple. A large variety of closely allied forms were found in water, resembling both these organisms. Test after test devised to distinguish the disease germs from the related bacteria broke down, and each failure discredited the isolations published by previous investigators. Even in the latest test of all, the Widal reaction with the blood serum of a typhoid patient, it appears that the difference between the typhoid germ and the normal intestinal bacillus is one only in degree and not in kind. The tubercle bacillus, the diphtheria bacillus, and many other forms can be identified with certainty by animal inoculation. Typhoid fever, however, cannot be communicated to the lower animals; and although there is no doubt as to the identity of the germ when isolated from the cadaver of a typhoid patient, its identification in water is still open to grave doubt. The attempt to find specific disease germs in sanitary water analysis has therefore fallen into disrepute.

The closely related forms which proved so great an obstacle in the isolation of the typhoid bacillus have, however, furnished a key to the problem. The commonest of them, the *Bacillus coli communis*, can be identified with comparative ease and certainty. When present in water it indicates, not the presence of infection, but that of fecal pollution. The probability that fecal pollution may imply infection is so strong that this test amply suffices for all practical purposes. During the last ten years the attention of sanitarians has been turned more and more from the direct to the indirect sign of danger, from the typhoid to the colon bacillus, on the theory that the occurrence of the latter implies the presence of sewage, and that any water containing sewage may safely be condemned. On the quantitative analysis, measuring, within certain limits, decomposing organic matter, — and the colon test, indicating more specifically that derived from intestinal discharges, — the bacteriological analysis of water is based.

TECHNIQUE OF QUANTITATIVE ANALYSIS.

The extreme delicacy of the test renders imperative the utmost care in the technique of bacteriological analysis; for a speck of dust, a delay of a few hours, or a mistake in the preparation of the nutrient gelatine, may introduce an error in excess of the normal

difference between the purest and the most polluted drinking-waters. First, in the collection of the sample, it must be certain that the small portion taken represents fairly the whole body of water from which it is drawn. The first water flowing from a tap or a pump must be rejected, as it may have acquired impurities from the mouth of the faucet or of the spout. On the other hand, water which has stood all night in the service pipes of a house will be lower in bacteria than the supply from which it is derived. In a lake or pond the surface scum and bottom sediment must be equally avoided.

In the second place, almost as soon as the sample has been collected, it begins to undergo change. As far back as 1879, Miquel observed that the number of bacteria in a sample of water ran up rapidly if it were allowed to stand before plating.* The light, the temperature, the predatory microörganisms, and other factors less clearly understood, are of more importance in keeping down the bacteria in nature than the lack of food supply; and the disturbance of these relations allows a rapid multiplication. In the purest natural waters, where the numbers are normally smallest, the increase on standing is most startling. Thus the Franklands record the case of a deep well water in which the bacteria increased from 7 to 495 000 in three days.† It is, of course, improbable that in absolutely pure water any such growth would occur, and Miquel found that in condensed water none took place.‡ Even the ordinary distilled water of the laboratory, however, contains sufficient food material to support ample bacterial life. The only sure way to avoid this difficulty is to plate the sample of water to be tested immediately after its collection; and for this end it would often be advisable to make the plates in the field. Plating samples out of doors or in a dusty room is, however, a difficult matter. As a rule, bacteriologists prefer to work in the laboratory, and to retard the development of the germs in transit by packing the samples in ice. This works well, if the delay be not too long, with relatively pure waters. With polluted waters, however, where the germs, and particularly the sewage forms, adapted to a high temperature, are abundant, a decrease occurs on standing, and the use of ice renders it more marked. Jordan found that three samples of river-water, packed in ice for forty-eight hours, fell off from 535 000 to 54 500;

* Miquel, Manuel pratique d'analyse bactériologique des eaux. Paris, 1891. p. 12.
† Frankland, P. and G., Microörganisms in Water. London, 1894. p. 223.
‡ Miquel, *loc. cit.*, p. 156.

from 412 000 to 50 500, and from 329 000 to 73 500, respectively.* It is thus evident that the bacteriologist must not only see to the collecting of his own samples, but must be intimately acquainted with their history until they reach his laboratory.

The third chance for error in bacteriological analysis is in the plating of the sample itself. The quantity of the water to be mixed with the melted gelatine must be so regulated by dilution that the number of colonies developing on the plate shall not be too small for average results, or so large that the growth of those which develop first will interfere with the slower forms. Less than ten colonies on a plate will probably produce discordant results; more than two hundred colonies will give numbers a trifle too low on account of antagonism. The thorough shaking of the sample at this point to secure an even distribution of the contained bacteria, and to separate those which may cling together so that a distinct colony may actually be formed from every germ present, is probably the most vital part of the whole process in securing comparable and accurate results.

In the fourth place, the chemical composition of the medium on which the germs are grown affects most fundamentally the results of the analysis. Of the three media in ordinary use for plate cultures, that made from meat juice, peptone, salt, and gelatine gives the highest figures, and that in which agar-agar, the jelly from a Japanese seaweed, is substituted for gelatine, gives the lowest. Glycerine agar, or the agar medium plus glycerine, is intermediate between the other two. The acid or alkaline reaction of the medium, too, was found as early as 1891 to be important, for Reinsch showed, in that year, that the addition of one one-hundredth of a gram of sodium carbonate to a liter of the medium increased sixfold the number of bacteria developing.† G. W. Fuller‡ and Sedgwick and Prescott,§ working independently, established the fact that an optimum reaction existed for most water bacteria, and that a deviation either way decreased the number of colonies developing. In accordance with this and other similar work, a definite standard method for making bacteriological media was outlined by a committee of the

*Jordan, E. O. Some Observations upon the Bacterial Self-purification of Streams. Journ. Exp. Med., V, 1900, p. 304.

†Reinsch, A. Zur bakteriologischen Untersuchung des Trinkwassers. Centr. f. Bakt., X, 1891, p. 415.

‡Fuller, G. W. On the Proper Reaction of Nutrient Media for Bacterial Cultivation. Public Health, XX, p. 381.

§Sedgwick, W. T., and Prescott, S. C. On the Influence of Variations in the Composition of Nutrient Gelatin upon the Development of Water Bacteria. Public Health, XX, p. 450.

American Public Health Association in 1897.* Such a uniform standard is an obvious necessity in order to secure the comparability of the results of various observers. Within limits, it is of no great importance that one method allows the growth of more bacteria than another. At best only a certain proportion of the total germs present in water appear in our artificial cultures. The common water spirilla, for example, and the widely distributed nitrifying organisms, are incapable of development in the gelatine plate. Our counts represent a section through the true bacterial flora, a section fairly representative of the ordinary water bacteria, and thoroughly representative of the quickly-growing, rich-food-loving sewage forms. It is only necessary that the proportion appearing should be the same in each experiment. It has been shown that the salt added to our media diminishes the number of bacterial colonies.† The substitution of certain special albumoses for gelatine would probably increase the numbers developing; Fuller and Johnson have even claimed that simple meat infusion and gelatine gives larger figures than the usual peptone gelatine.‡ Yet these changes will not be made until they can be introduced by a general consent among bacteriologists. Comparability is the one vitally essential factor.

In the fifth place, the investigator may not relax his watchfulness even after his plates are made, for the conditions under which they are kept or "incubated" must be looked to. Development will occur satisfactorily only in the dark; Arloing showed that some of the most resistant of all disease germs, the spores of anthrax, were killed by direct sunlight in two hours under favorable conditions;§ and even diffused light hinders the growth of the water bacteria. Moisture must be present, for otherwise, according to Whipple's experiments,‖ the surface gelatine forms a hard film in drying which may keep counts twenty-five per cent. below their normal value. According to the same author, the bacteria are so sensitive to

* Report of a Committee of Bacteriologists to the Committee of the American Public Health Association, on the Pollution of Water Supplies. Public Health, XXIII, p. 56. A new report on the subject was made at the Buffalo meeting of the American Public Health Association in September, 1901, in which the standard methods of procedure were extended and modified to some extent.

† The addition of salt is abandoned according to the new standard procedure of 1901.

‡ Fuller, G. W., and Johnson, G. A. On the Question of Standard Methods for the Determination of the Numbers of Bacteria in Waters. Public Health, XXV, p. 574.

§ Arloing. Influence de la Lumière sur la Végétation et les Propriétés pathogènes du Bacillus anthracis. Compt. Rendus, Vol. 100, 1885, p. 378. Also Vol. 101, pp. 511 and 535.

‖ Whipple, G. C. On the Necessity of Cultivating Water Bacteria in an Atmosphere Saturated with Moisture. Technology Quarterly, XII, 1899, p. 276.

changes in the amount of oxygen that the bottom plates in a pile show smaller numbers than the upper ones on account of the exhaustion of this gas by the bacterial growth above.

Finally, the sixth problem for the bacteriologist is to determine the time he shall allow to elapse before the colonies on his plates are counted. The rapidity with which different species develop varies widely. Miquel states * that only seventy-five per cent. of the water bacteria, capable of growth on gelatine, formed visible colonies during the first week, and French bacteriologists still continue to recommend an incubation period of from seven to fifteen days. German official regulations, on the other hand, call for a forty-eight hour period; and in this country counts are usually made on the third or the fourth day. In practical sanitary work there can, I think, be no doubt of the wisdom of adopting an arbitrary short period of time. The practical conditions of the laboratory forbid the storage of large numbers of plates for weeks and months. Furthermore, the sewage bacteria, in which the sanitarian is chiefly interested, develop rapidly. The slowly growing forms have for him but little significance, and to include them in his counts would be useless if not misleading. Here again the ideal of the bacteriologist is to furnish conditions favorable to a large proportion of water bacteria, and to insure the constancy of the conditions in all his experiments.

INTERPRETATION OF QUANTITATIVE ANALYSIS.

The older experimenters attempted to establish arbitrary standards, by which the sanitary quality of a water could be fixed automatically by the number of germs alone. Thus Miquel furnished a table according to which water with less than 10 bacteria per cubic centimeter was "excessively pure," with 10 to 100 bacteria "very pure," with 100 to 1 000 bacteria, "pure," with 1 000 to 10 000 bacteria, "mediocre," with 10 000 to 100 000 bacteria, "impure," and with over 100 000 bacteria, "very impure."† Few sanitarians would care to dispute the appropriateness of the titles applied to waters of the last two classes; but many bacteriologists have placed the standard of "purity" much lower. The limits set by various German observers range, for example, from 50 to 300. Even Dr. Sternberg, in a much more conservative fashion, has stated that a water containing less than 100 bacteria is presum-

* Miquel, *loc. cit.*, p. 83. † Miquel, *loc. cit.*, p. 129.

ably from a deep source and uncontaminated by surface drainage; that one with 500 bacteria is open to suspicion; and that one with over 1 000 bacteria is presumably contaminated by sewage or surface drainage.* This is probably as satisfactory as any arbitrary standard which could be devised, but any such standard must be applied with great caution. The source of the sample is of vital importance in the interpretation of analyses; a bacterial count which would condemn a spring might be quite normal for a river; only figures in excess of those common to unpolluted waters of the same character give the indication of danger. Thus in pure rain water, bacteria, if present at all, range usually only from units to tens. In springs and deep wells it was once believed that sterile water could be found; but Sedgwick and Prescott and others have shown that this is fallacious.† The observers mentioned found sometimes two and three hundred bacteria in unpolluted deep wells and in woodland springs among the hills of New Hampshire; more commonly, however, the bacteria in water of this class will be measured also in units and tens. In lakes the point at which the sample is taken is of great importance, as the bacterial content varies with the distance from shore and with the depth below the surface. Ordinarily the counts will not fall below ten nor rise above five hundred. Finally, the water of rivers, even when unpolluted by sewage, may, at times, contain thousands of bacteria. The season of the year in this case is a controlling factor of importance. As will be seen from the three instances in the subjoined table, the bacterial counts are highest in the winter and spring months, and lower from April to September.

NUMBER OF BACTERIA PER CUBIC CENTIMETER IN CERTAIN SURFACE WATERS.

Water	*Year*	*Observer*	*Jan.*	*Feb.*	*Mar.*	*April*	*May*	*June*
Boston Tap Water	1892-5	Whipple‡	135	211	102	52	53	86
Merrimac River .	1899	Clark§	4 900	5 900	6 300	2 900	1 900	4 700
Thames River . .	1888	Frankland‖	92 000	40 000	66 000	13 000	1 900	3 500

* Sternberg, G. M. Manual of Bacteriology. New York, 1892. p. 562.

† Sedgwick, W. T., and Prescott, S. C. On the Bacterial Contents of Certain Ground, Waters, Including Deep Wells. Twenty-Sixth Ann. Rep., State Board of Health of Mass., 1894, p. 435.

‡ Whipple, G. C. Journ. N. E. W. W. Assoc., X, p. 217, June, 1896.

§ Thirty-First Annual Report, State Board of Health of Mass., 1899, p. 486.

‖ Frankland, *loc. cit.*, p. 90.

NUMBER OF BACTERIA PER CUBIC CENTIMETER IN CERTAIN SURFACE WATERS. — *Continued.*

Water	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Boston Tap Water	73	81	86	55	56	52
Merrimac River	3 700	5 000	5 200	9 300	9 800	9 800
Thames River	1 070	3 000	1 740	1 130	11 700	10 600

This spring increase in the content of surface waters is not an exception to the rule that high numbers are dangerous, but an excellent illustration of it. At this season of the year, rivers and small unprotected reservoirs are heavily polluted by melting snow and washings from the surface of the ground, and it is precisely at such times that specific infection of surface supplies and water-borne epidemics of typhoid fever are most likely to occur: witness the disastrous New Haven epidemic of last spring and the regular spring typhoid in Philadelphia and Chicago.

In all these cases it is, of course, not the large numbers of bacteria, in themselves, which are directly harmful. The real source of danger lies only in the comparatively small proportion of disease germs, so small a proportion as to be practically beyond the reach of our method of analysis. But excessive numbers of bacteria, except under peculiar conditions, to be noted later, point, like the free and albuminoid ammonia of the chemist, to the presence of organic matter, and, with much more certainty and delicacy than do those compounds, to the presence of putrifying or recently putrifying organic matter. Such organic matter can scarcely, under practical conditions, gain access to a water supply except from sewage or from fresh surface drainage. In either case the entrance of the specific germs of disease is a possibility, and the water, for safety, should not be delivered to consumers.

It has often been said that single bacterial analyses are valueless; but this, I think, can scarcely be maintained. Knowing the normal bacterial range for a water of a certain class, even an isolated analysis may show such an excess as to have great significance. In the spring of 1900, for example, Mr. Henry Souther and I made a few analyses of the water from the double source of supply used at that time by the city of Hartford, Conn. The first plates we made showed us that the water from the Connecticut River contained from

four thousand to seven thousand bacteria per cubic centimeter, with *Bacillus coli* constantly present, while that from the impounding reservoir normally used by the city contained three hundred to nine hundred bacteria and only rarely was *Bacillus coli* found. Armed with this tangible evidence, Mr. Souther forcibly called the attention of the authorities to the danger from the supplementary river supply, which was at once discontinued. Later it appeared that there were twenty-five deaths from typhoid fever during the four months when the river water was in use, against seventeen in the ten months before, and twenty-five in the twelve months after that period. One more instance from my own recent experience: In the typhoid epidemic at Newport, R. I., a year ago, there was some popular suspicion of the public water supply. The chemical analysis was not quite reassuring; but there were only 334 bacteria present per cubic centimeter and no *Bacillus coli*. The water from a well in the infected district, on the other hand, gave 6 100 bacteria per cubic centimeter, and *Bacillus coli* in abundance.* It was no surprise to find, on a further study of the epidemic, that the well was largely responsible for the trouble and the public supply not at all.

It is of course true that the significance of bacteriological analysis is greatly enhanced by the study of series of results covering long periods of time. Its most important function will, doubtless, always be to aid in the supervision of large city supplies where systematic examination gives normal values, from which any deviation will at once be noted. In Chicago, for instance, daily analyses, both chemical and bacteriological, are made, and warnings based on the results are issued to the public; and the relation between bacterial counts and the prevalence of water-borne disease has been found to be striking. It was stated in the official report of the department for 1896 that "the rise in the water pollution line is followed with almost mathematical accuracy by a rise in the death lines of the acute intestinal diseases and of typhoid fever — the former reaching a maximum usually within a week, the latter within five or six weeks."† The study of the effluent from municipal water filters is closely allied to such regular supervision of unfiltered

*Winslow, C.-E. A. Typhoid Fever at Newport, R. I., in 1900, and Its Relation to Defective Sanitation. Technology Quarterly, XIV, p. 110.

†Gehrmann, A., and Kennicott, C. L. The City Water Supply. Biennial Report, Department of Health, Chicago, 1895-96, p. 175.

supplies. Here indeed bacteriology furnishes the only possible method of control; breaks in the filtering layer, which could be detected in no other way, are at once made manifest by a rise in the bacterial content of the effluent. In Germany regular bacteriological analyses of raw and filtered water are obligatory, and in this country and in England they are being recognized as indispensable.

Next to such series of analyses, in which the water from the same source is compared at different times, come the elaborate studies made of late years as to the exact distribution of streams of sewage in the bodies of water into which they flow, their disappearance by dilution and their removal by self-purification. The fate of the South Metropolitan sewage in Boston Harbor has been studied in this way at the Institute of Technology, and its course, as it is carried out by the tide, mapped out by its high bacterial content with greater accuracy than could be attained by any other method. Some very remarkable facts have been developed by these studies as to the persistence of separate streams of water in immediate contact with each other. Heider showed that the sewage of Vienna, after its discharge into the Danube River, flowed along the right bank of the stream, preserving its own bacterial characteristics, and not mixing perfectly with the water of the river for a distance of more than twenty-four miles.* And Prof. E. O. Jordan, in studying the self-purification of the sewage discharged from the great Chicago drainage canal, found by bacteriological analyses that the Des Plaines and the Kankakee rivers could both be distinguished, flowing along in the bed of the Illinois, the two streams being in contact, yet each maintaining its own individuality.†

There is, as I have noted above, one exception to the rule that high numbers of bacteria imply the presence of putrifying organic matter. The abnormal increase in samples kept bottled before plating has been described; under certain conditions, not clearly understood, particularly in rather pure ground waters, such a multiplication may occur under natural conditions. In all such cases, however, the prevailing bacteria belong exclusively to one or a very few species of non-sewage organisms. Dr. E. K. Dunham cites a

* Heider, A. Untersuchungen über die Verunreinigungen der Donau durch die Abwässer der Stadt Wien. Das österreichische Sanitätswesen, 1893. Belage zu Nr. 31, 3.

† Jordan, E. O. Some Observations upon the Bacterial Self-purification of Streams. Journ. Exp. Med., V, 1900, p. 272.

very instructive example of this sort.* The mixed water from a series of driven wells gave two bacteria per cubic centimeter, while another well, situated just like the others, contained five thousand, all belonging to a single species common in the air. Such cases as this would be very easily distinguished by a casual examination from the crowded medley of colonies of different species, many of them liquefiers and some characteristic sewage forms, which we get from a polluted water. The general appearance of the plates, then, must be considered in interpreting the results of an analysis.

ISOLATION OF THE TYPHOID BACILLUS.

After what has been said already, it is not necessary to dwell at any length upon the methods suggested for the discovery of the specific organism of typhoid fever. The examination of colonies isolated on plates made directly from the suspected water has not been relied on except by a few observers, on account of the small chance of finding the disease germs in the host of ordinary fecal forms. As a rule some preliminary process of "enrichment" precedes the plating; that is, a portion of the water is kept for a time under conditions which will favor the growth of any typhoid bacilli present while retarding the growth of other forms, the result being a considerable increase in the relative numbers of the former. This is practically effected by mixing the sample with nutrient fluid containing a small percentage of free acid, and by incubating it at the body temperature. Finally, Klein and some other observers have increased the chances of success to a maximum by passing a large quantity of water through a Pasteur filter and examining the mass of bacteria concentrated upon its surface.†

All these precautions are, however, insufficient to secure a satisfactory separation of the typhoid germ. The difficulty with the enrichment process is that the acids and the high temperature, although fatal to many water bacteria, are somewhat less inimical to the colon bacillus, the common sewage form, than to the typhoid bacillus itself. The former have, therefore, a strong tendency to overgrow and kill out the latter. Hankin, of the British Army Medical Corps in India, claims to have obviated the difficulty by the following

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*Dunham, E. K. On the Bacteriological Test of Drinking Water. Medical Record, 1889, p. 367.

†Klein, E. Report on an Epidemic of Enteric Fever in the Borough of Worthing. Twenty-Third Annual Report, Local Gov't Board, 1893-94, Supplement, p. 47.

process.* He adds portions of the water to be tested to tubes containing successively increasing proportions of Parietti solution (four per cent. hydrochloric and five per cent. carbolic acid or phenol). The tubes at the bottom of the series, in which the acid is not too strong, become turbid; and instead of taking the tube with the highest amount of acid in which growth occurs (which would probably contain only *Bacillus coli*), Hankin takes the one just below for the inoculation of a new series. Finally pure cultures are isolated on the agar plate and tested by various sub-cultures.

The positive identification of the typhoid bacillus offers more serious difficulties than its separation, and many of the papers published on the subject are quite valueless because this step has not been carried out with proper caution. In the first place most of the tests relied on are negative in character, and designed to distinguish the typhoid from the colon germ, which latter possesses a number of biochemical powers which the former does not. Any determination based largely on negative characters must be dubious because external conditions may temporarily suppress almost any of the characteristics of an organism. Of the forty or more observers who have claimed to have found the typhoid bacillus in water, all but the most recent are quite discredited on account of the insufficiency of their confirmatory tests. When, however, Widal suggested the testing of the suspected germs by placing them in the blood serum of a typhoid patient, which has the property of causing the germs of the disease to "agglutinate" or clump together and become motionless, it seemed that a great stride had been taken. Relying mainly on this test and more neglectful than ever of the other characteristics of the organism, a new series of typhoid isolations has been published. Two French observers, Remlinger and Schneider, found typhoid bacilli everywhere, in water, in soil, and in the feces of healthy individuals.† A German bacteriologist last year made twenty-eight gelatine plates directly from the water of a suspected cistern, and isolated eleven typhoid cultures from them.‡ Hankin has found the disease germs in abundance in the outer world.§ It now ap-

*Hankin, E. H. On the Detection of the Bacillus Typhi Abdominalis in Water and Other Substances. Centr. f. Bakt., XXVI, 1899, p. 554.

†Remlinger, P., and Schneider, G. Contribution à l'étude du bacille typhique. Ann. de l'Inst. Past., XI, 1897, p. 55.

‡Genersich, W. Typhusepidemie durch Typhusbakterien infizierties Trinkwasser. Centr. f. Bakt., XXVII, 1900, p. 241.

See Arb. a. d. Kaiserl. Gesundheitsamt, XI, 240; Arch. f. Hyg., XXXVI, 178; and Centr. f. Bakt, XXIX, 329, for other recent isolations.

§Hankin, *loc. cit.*

pears, however, that the colon bacillus also is agglutinated by typhoid serum, although in less dilute solution; and that the test is complicated by many unsuspected sources of error.* The absolute specific character of the reaction thus receives a severe blow; and it becomes evident that the serum test alone, without any elaborate study of other reactions, is not sufficient to establish the identity of the typhoid bacillus.

The main reason for receiving the reports of the observers mentioned above with skepticism is that they prove too much. If typhoid germs were present in such abundance in drinking-water, the human race must long ago have been exterminated, or else have acquired an immunity that would render epidemics impossible. The analyses have usually been made some time after the infection of the supply; but typhoid germs are not supposed to persist in natural waters for any very extensive period. Laboratory experiments have shown that they may live in sterilized water for weeks and even months, but that in normal water, under competition with the ordinary water bacteria, they disappear in a few days or, at the outside, in two or three weeks. Epidemiological experience confirms this conclusion, as the cases of typhoid fever caused by a single infection of a water supply are always grouped rather closely about a certain date. Even at the height of infection, the specific bacteria are relatively few in number. Laws and Andrews failed to find the typhoid bacillus at all in the sewage of London, and isolated only two colonies of the germ from a long series of plates made from the sewage of a hospital containing forty typhoid patients.†

Common sense teaches that these observers and not Remlinger and Hankin must be right. I do not think it too much to say that the isolation of the typhoid germ from water has never yet been satisfactorily proved. A positive result of the search for this germ is, therefore, scarcely to be hoped for. A negative result has no significance; and the complexity of the process renders it quite unfit for practical use.

ISOLATION OF THE COLON BACILLUS.

The colon bacillus or *Bacillus coli communis* was first isolated by Escherich, in 1885, from the feces of a cholera patient, and it was

*Jatta, M. Experimentelle Untersuchungen über die Agglutination des Typhusbacillus und der Mikroorganismen der Coligruppe. Zeit. f. Hyg., XXXIII, 1900, p. 185.

† Laws and Andrews. Report on the Microörganisms of Sewage. Reports to the London County Council, 1894, No. 216.

later found to be the normal inhabitant of the intestinal tract of man and the higher animals. It was not till about 1894 that the examination of water for this organism began to be widely used as a sanitary test, and it is gratifying to note, as an instance of the keen common sense so characteristic of American science, that it has been principally developed in this country. The work of Dr. Theobald Smith in regulating the details of the study of the fermentative power of the bacillus; of Prof. W. T. Sedgwick, under whose direction Dr. A. P. Matthews introduced the Wurtz lactose-litmus-agar process into America in 1893; of Prof. E. O. Jordan, of H. W. Clark, of G. C. Whipple, of W. R. Copeland, and of E. E. Irons may be especially referred to.

The isolation of the *Bacillus coli communis* includes three main processes, — the enrichment of the water by incubation at the body temperature, the separation of pure cultures by plating, and the testing of these pure cultures by inoculation into various other media in order to see whether they possess all the characters of the typical organism. The first step is to introduce a measured quantity of the water, usually a cubic centimeter or a fraction of a cubic centimeter, into a Smith tube filled with a nutrient solution containing dextrose. After twelve hours at the body temperature, any bacilli of the colon group, or of a number of allied groups, will have multiplied enormously, and decomposed the dextrose, producing gas which collects in the closed arm of the tube. If no gas is formed, colon bacilli are absent, and the test need be pursued no further. As in the case of the typhoid isolation, although to a much less extent, there is a danger in the enrichment process that other forms may overpower and kill out a smaller proportion of colon bacilli. The addition of a small amount of carbolic acid or phenol has been suggested in this case, too, as a remedy; and some observers have, I believe, found it successful.* In my own experience it has not worked well with highly polluted waters, which are the only ones in which a harmful overgrowth is likely to occur. The intruding organisms throve on the phenol, and I obtained a smaller percentage of positive results with it than without. The simplest method appears to be to omit the enrichment process altogether in these highly polluted waters and to proceed at once to the lactose-agar plate. With relatively

* Irons, E. E. Some Observations on Methods for the Detection of B. coli communis in Water. Public Health, XXVI, 1900, p. 310.

pure waters, on the other hand, the preliminary incubation in dextrose broth is always of advantage.

If gas be formed in the Smith tube, it is evident that some organism is present which has the power of fermenting dextrose. The next step is to isolate the germs in pure cultures. A very minute portion of the culture in the Smith tube is added to agar containing lactose or milk sugar and some blue litmus, and plated. Now, *Bacillus coli* ferments lactose as well as dextrose, and produces acid which turns the blue litmus red. Colon bacilli, if present, will therefore produce in twelve hours red colonies on a blue ground, and later will turn the whole plate red. After twenty-four to thirty-six hours, the plate will become blue again as the bacteria proceed to attack the nitrogenous matter present and produce ammonia, which renders the medium alkaline once more. This action on lactose has been used by some bacteriologists under the name of "the Kashida test" (Kashida hav- suggested its use merely to differentiate the colon from the typhoid bacillus *), as a complete demonstration of the presence of fecal bacteria. It is obvious, however, that it signifies simply the presence of some organism capable of fermenting lactose, and there are plenty of such organisms which do not belong to the colon group.

In order to have any value, the test must be carried much further, and must include the study in detail of pure cultures from the red colonies on the litmus-lactose-agar plate. Several colonies from each plate should always be examined; I have systematically used three in my own work, and have sometimes found one giving positive results while the other two were negative. Just what characters to use in defining the "colon bacillus" is a matter of prime importance. The whole question of species among the bacteria is an extremely complex one. Around each definite species are grouped forms differing from the type in one or two of its characteristics. Dr. W. W. Ford has just published descriptions of forty-eight varieties of bacteria isolated from the human intestine, and differing from each other almost imperceptibly.† These variations are often related to the physical conditions surrounding the organism. Bacilli are commonly found in water which might easily be colon bacilli slightly modified by their unusual environment. The more of these forms which are included,

* Kashida, K. Differenzierung der Typhusbacillen vom Bacterium coli commune durch die Ammoniakreaktion. Centr. f. Bakt., XXI, 1897, p. 802.

† Ford, W. W. Classification of Intestinal Bacteria. Journ. of Medical Research, VI, p. 211.

the greater will be the number of positive isolations. At present our definitions must be more or less arbitrary; each observer will consider as true colon bacilli those which fulfill his particular set of tests, and will class as pseudo-colon organisms those which do not. If we find, having established such an arbitrary standard, that the colon bacillus, as determined by it, is found in waters known to be polluted, and not, as a rule, in those known to be free from pollution, the sanitarian can afford to ignore the theoretical question of specific values, and make confident use of the practical test. It is of course highly desirable that some standard set of reactions should be commonly adopted by sanitary bacteriologists; I hope some such uniform scheme may soon be drawn up by the Society of American Bacteriologists or by the American Public Health Association. At present the plan in use by the Massachusetts State Board of Health and at the Institute of Technology is most widely prevalent in this country. It involves the use of six simple, definite, positive tests, — the growth in gelatine, lactose agar, dextrose broth, milk, nitrate solution, and peptone solution.

The colon test must always, of course, be to some extent quantitative; that is, the organism is found, or is not found, in a certain definite quantity of water. The usual portion is one cubic centimeter; but often one hundred centimeters or even a liter is "enriched" by incubation with the addition of sugar and phenol, and the Smith tube is inoculated from the enriched solution on the following day. With comparatively pure waters the colon bacillus will sometimes be found by this process when a number of one cubic centimeter samples taken at random from the original water would give negative results. The use of these large samples is, however, of very doubtful value; for the presence of *Bacillus coli* in numbers too small to be detected in one cubic centimeter has little sanitary significance. With more polluted waters the use of large portions is not only unnecessary but harmful, on account of the danger of overgrowth by other forms; in such waters, one cubic centimeter will frequently give a positive, one hundred cubic centimeters a negative, result.

On the other hand, it is highly desirable to know whether the colon bacilli present in one cubic centimeter are numbered in units or thousands. This can easily be determined by testing fractional parts of the cubic centimeter in the usual way. If, for example, hundredths of a cubic centimeter give positive, and thousandths negative results, between one hundred and one thousand of the organisms are

present in the unit quantity. Another quantitative method, suggested, I think, by Copeland,* and in use in some of our best laboratories, consists in the enumeration of the red colonies on lactose-agar plates made from the water direct, with or without the addition of phenol. It is of course impossible to work out all the colonies in detail, and the observer must trust to his eye to distinguish the colon colonies from those of other germs which ferment lactose. Personally, I do not think that this distinction can be trusted; and the records of the number of colon bacilli in a water carried down to units suggests to me a "false and delusive accuracy." The quantitative estimation by the examination of fractions of a cubic centimeter, on the other hand, is thoroughly scientific, and its results are quite close enough for sanitary purposes.

SIGNIFICANCE OF THE COLON BACILLUS.

The colon test has been received by engineers and practical sanitarians with great satisfaction, and has been applied with confidence to the examination, not only of water, but of shellfish and other articles of food as well. On the other hand, certain European bacteriologists within the last two or three years have denied its value. Poujol found the colon bacillus in the water from supposedly unpolluted deep wells;† and Weissenfeld declared, less than a year ago, that the "so-called *Bacillus coli* may be isolated from water from any source, good or bad, if only a sufficiently large quantity of the water be used."‡ The results of these observers are due, however, to two defects in their experiments. In the first place, the tests of the identity of the *Bacillus coli* have been usually quite inadequate, and many forms have therefore been included which are not colon organisms; in the second place, the use of large volumes of water vitiates any practical conclusion from the researches.

The colon bacillus is not confined to the human being. Dyar and Keith§ and Smith‖ have found it in the intestines of cats, dogs,

*Copeland, W. R. The Use of Carbolic Acid in Isolating the Bacillus coli communis from River Water. Journ. Bost. Soc. Med. Sci., V, p. 381.

†Poujol, G. Sur la présence très fréquente du bacterium coli dans les eaux naturelles. Comptes rendus de la Soc. de Biol., 1897, p. 982.

‡Weissenfeld, J. Der Befund des Bacterium coli im Wasser und das Thierexperiment sind keine brauchbaren Hülfsmittel für die hygienische Beurtheilung des Wassers. Zeit. f. Hyg., XXXV, 1900, p. 78.

§Dyar, H. O., and Keith, S. C. Notes on Normal Intestinal Bacilli of the Horse and of Certain Other Domesticated Animals. Technology Quarterly, VI, 1893, p. 256.

‖Smith, T. Ueber den Nachweis des Bacillus coli communis im Wasser. Centr. f. Bakt., XVIII, p. 494.

swine, cattle, hens, and turkeys. A bird flying over a reservoir or a cloud of dust blown from an adjacent roadway might easily produce sufficient pollution to give positive results when large volumes of water are used, and even in occasional single cubic centimeters. But there is no evidence that the colon bacilli originate anywhere else than in the intestinal tract of the higher vertebrates, the only natural environment in which they can find the high temperature and the rich food supply of peptones and carbohydrates to which they are adapted. As Dr. Smith has said, "They are widely distributed in nature mainly because fecal discharges of human beings and animals are a common thing on the soil."*

When the colon bacillus, as defined by the tests noted above, is found in such abundance as to be isolated in a large proportion of cases from one cubic centimeter of water, it is reasonable proof of the presence of serious pollution. Even Weissenfeld's own results show this. In the presumably good waters which he examined he found his imperfectly defined colon bacillus eight times in one cubic centimeter, and twenty times only when he examined a liter; while in the polluted waters he isolated the organisms twenty-four times from one cubic centimeter and twice from a liter only. During the past winter, I examined fifty-eight samples of water from presumably unpolluted sources, including the supplies of Boston, Brookline, Needham, Taunton, Lynn, and Cambridge, and certain bottled spring waters; in only two cases, one out of nine Boston samples and one out of nine Cambridge samples, was a positive result obtained in one cubic centimeter. In one other Cambridge sample, the colon bacillus was isolated from one hundred cubic centimeters; and in nine other cases forms were found which produced red colonies on lactose agar, but were not colon bacilli. Even in twenty-one samples from stagnant ditches and pools and other sources, probably not receiving sewage, but all more or less foul with decaying organic matter, I found the organism only five times in one cubic centimeter and in three others when one hundred cubic centimeters were examined. In nine of the remaining thirteen instances, pseudo-colon bacilli were present which would have been included by the use of the lactose-agar plate alone. If, on the contrary, fresh sewage be really present even in infinitesimal amount, the test must be positive.

Klein and Houston experimented by diluting sewage with distilled water and testing the mixture; they found that a proportion so small

*Smith, T. Water-borne Diseases. Journ. N. E. W. W. Assoc., X, p. 203.

as to be quite indistinguishable by chemical analysis was readily detected by the colon test.* When the underdrains of the Lawrence city filter were relaid in December, 1898, the sand was disturbed and a small typhoid epidemic resulted; Clark and Gage observed that the colon bacilli in the filter effluent were found in one cubic centimeter in seventy-two per cent. of the samples examined instead of in less than ten per cent., as had previously been the case.†

The experience of all who have practically applied the test has, I think, been the same. In delicacy it surpasses chemical analysis; in constancy and definiteness it excels the quantitative bacterial analysis; as an aid and accessory to both it will find an increasing usefulness in the future.

DISCUSSION.

Mr. George E. Winslow.‡ I understood Mr. Winslow to say in his paper that bacteria are in larger numbers in river-waters than in spring waters or ground waters; and I would like to ask him what would be the result of allowing river-water to mix with a spring or ground water, not in large quantities, but perhaps one or two per cent. of river-water; would it be detrimental to the quality of the spring water?

Mr. C.-E. A. Winslow. The mixture of river-water or any surface water with ground water introduces a small proportion of bacteria directly, and also a considerable amount of food supply which would enable those bacteria, and those already present in the ground water, to multiply. I should say it would undoubtedly have a bad effect in those two ways.

Mr. George E. Winslow. The reason I speak of this is on account of the bad effect which I think has resulted to the water in Waltham, which comes from the ground, from letting in a small amount of river-water, which was claimed to be for the purpose of experiment, to see how much water could be obtained by what they call "filtration," as the amount they will require in the future will possibly be larger than the well can supply. The effect has been to

*Klein, E., and Houston. Report on the Bacteriological Evidence of Presumably Recent and therefore Dangerous Sewage Pollution of Elsewise Potable Waters. Rep. of Med. Off. of Local Gov't Board, 1897-98, p. 318.

†Clark, H. W., and Gage, S. D. The Significance of the Appearance of B. coli communis in Filtered Water. Journ. Bost. Soc. Med. Sci., IV, 1900, p. 172.

‡ Waltham, Mass.

produce a large amount of life, so much that it made the water taste bad.

I objected very strongly to that water being let in, not only on account of the liability of introducing harmless bacteria, but because of the dangerous bacteria which might be in the river. They claimed they could do it safely, that there would be no trouble; but I held that it would really be detrimental to the water. But what I wanted to know particularly was whether it was of any advantage to ground water, or whether it was unsafe or detrimental; and then I should also like to know, if you can inform me, whether it increases the amount of vegetable form of life in the ground water.

Mr. C.-E. A. Winslow. The growth conditions for bacteria and for other forms of vegetable life are quite different. The food supply of bacteria consists of organic matter; that of the green plants consists of mineral matter, — nitrates for example. The river-water would introduce the food supply for the bacteria, but the green plants would find an ideal food supply already in the ground water. That is why the effect on the growth of microscopical organisms, aside from bacteria, has always been so bad when ground water, containing food for the green plants, and river-water, containing spores of the green plants, have been mingled. In Brooklyn, for instance, it has caused very serious trouble. There is only one other thing necessary, and that is light. If the reservoir in which this mixed water is stored is covered, multiplication will not occur, but when you have microscopical organisms, food supply, and light, you are bound to get an enormous multiplication.

Mr. George E. Winslow. I can say from observations that I have made that you are right in that. The water was so disagreeable to the taste, and so disagreeable to use in washing clothes, that I, as an interested citizen, visited the reservoir and pumping station. I found the water was very turbid, — you could n't see down more than a foot and a half in depth through the water, — and that caused me to go to the station to find out whether they were running any river-water in, and I found water running in through a six-inch pipe from the filter. To be sure the pipe was n't running full, because it could n't fill the outlet with the head it had, but it did run, say, from thirty thousand to fifty thousand gallons a day, and I found my suspicions were confirmed. I went to the superintendent and talked with him about it, and he could n't see any objection to it, and quoted the State Board of Health's analysis to back up

what he was doing. I objected to it in my talk with him, on account of the dangers from disease, and I also objected to it on account of its increasing the vegetable forms. He paid but very little attention to me, but I made up my mind that it had got to stop. I interested some of our aldermen, and the result was that it was stopped, and the trouble is now disappearing. I went up there some two weeks after the water was shut off from the river, and I found, instead of its having a greenish look and being so dense, it was turning a brownish color. I concluded that the vegetable forms were decaying and that they would gradually settle and the water become clear. I have n't seen it now for over a week, but I do know that we are getting very much clearer water in the city, and I concluded that the river-water was the principal cause of our trouble. Your statement rather shows the same thing.

MR. C.-E. A. WINSLOW. Of course I don't know about this specific case at all, but I do not think the addition of river-water to a ground water supply could be possibly justified, as far as regards the question of green growths, or on sanitary grounds. For a city that has a safe supply, as a ground water presumably is, to add river-water, which is, I think, recognized by all sanitarians now as dangerous, is clearly a mistake.

MR. W. C. HAWLEY.* Would that apply to a case of mixing ground water and surface water where the waters are taken directly to the mains and distributed from the distribution system?

MR. C.-E. A. WINSLOW. It would not apply to the growth of microscopical organisms but it would apply to the sanitary danger, if it was river-water. I do not think unfiltered river-water is ever safe to drink; but it would not cause the growth of organisms if delivered at once to the consumer.

MR. J. C. WHITNEY.† I would like to ask Mr. Winslow what filtering process took place in the case of this river-water he speaks of.

MR. GEORGE E. WINSLOW. In my talk with Mr. Brown, the superintendent, he claimed that the water coming from the river was practically pure; that is, purified from all germs and from all dirt. I asked him how his filter was constructed. He said the water went through from twelve to twenty-five feet of gravel to get to the filter

* Superintendent of Water Works, Atlantic City, N. J.
† Water Commissioner, Newton, Mass.

gallery, as we call it; but from my observation I should say it went through considerably less than that. The filter is made by putting in a coarse material at the bottom between the gallery and the river, and then filling in with finer material until it is brought to the surface and covered; that allows the water to run through from the river to this gallery, which is about fifty feet long, two and a half feet wide, and seven feet deep. The earth between that and the basin where our pure water is, is practically impervious to the flow of this water from the river; very little runs through there. He said he built the filter last fall, a year ago. I asked him if he took readings to know how much water went in, and he said he had. I asked him if there had been any decrease in the flow of water, the amount which would go through this bank, and he said, "It runs the same now as when first built." I told him I thought his "filter" was a mighty good strainer but a very poor filter.

I found on looking where the water emptied from this six-inch pipe upon the stone work in the basin, before it ran into the water in the basin, a space perhaps two feet long by four inches wide, and at the deepest place there was a deposit of decomposed vegetable matter, about an inch and a half thick. I took some of it up and found it was a nice, rich hard mud, and that showed that there was some dirt coming in with the river-water, and that was one reason I made so strong a claim that the river-water should be cut off, because the filter did n't take all the dirt out of the water, and if there were any disease germs in the river they had a grand chance to get in and mix with our spring water and come to us in the city. The chances for disease from Charles River water I consider very large, because there is a very large amount of boating and a number of pleasure grounds and houses along the river.

MR. M. F. COLLINS.* I would like to ask Mr. Winslow a question, although it may be traveling a little outside of the subject he was considering, and that is this: If after cleaning your filter you run for a week or two, and your negative loss of head, we will say, is three feet, and you have a vegetable layer forming on top of your sand, and your head remains about the same, whether that is injurious to the water which is going through the filter or a benefit to the water.

MR. C.-E. A. WINSLOW. Do you mean whether a deposit of green growth is harmful or beneficial?

* Superintendent Lawrence (Mass.) Water Works.

MR. COLLINS. Yes, sir.

MR. C.-E. A. WINSLOW. It is beneficial, I should say, decidedly, from a sanitary standpoint. Anything which adds to the straining effect is good.

MR. COLLINS. Let me ask you another question. Would you clean that bed as long as your negative loss of head is what you would consider within safety, or would you allow the water to run through that vegetable growth, instead of attempting to clean it, if it was vegetable growth and nothing more?

MR. C.-E. A. WINSLOW. I should think the limit would be purely an economical one.

MR. COLLINS. You would let it run as long as you could get a sufficient supply?

MR. C.-E. A. WINSLOW. Let it run as long as it was economical to do so; that would be proper from a sanitary standpoint.

MR. COLLINS. That is what I wanted to know. You think it would n't have a tendency to do the water any damage, by allowing that vegetable growth to remain?

MR. C.-E. A. WINSLOW. That would depend upon the character of the growth. There are essential oils produced by some organisms which would not be removed by filtration.

MR. COLLINS. About two weeks after cleaning our filter in the month of August, we had occasion to draw the water off from the filter. There was a green slimy growth all over it. We left the water off for about two days and that all burnt up. Then we let the water run on again, and the loss of head was about what it was before, and that continued for two weeks. I think we cleaned the filter again on the 28th or 29th of August, and we drew the water off on Labor Day, and there has been quite a growth within the week, but our loss of head is n't any greater than it was two weeks ago. That is the reason I would like to know from you, as a scientist and an expert in this matter, whether it would n't be a benefit to allow this to remain on and help the filtering process; or would you attempt to clean your bed this time of the year as long as you could get water enough through the vegetable growth?

MR. C.-E. A. WINSLOW. The green growth could not be of any sanitary disadvantage. It could n't cause disease. It might cause a taste in the water, but your experience ought to have taught you whether it does or not.

MR. COLLINS. I don't think it does, and our filter has been run-

ning so well, and we have been getting such a good supply of water through it with this growth on it, that I believed it would be a benefit, and I wanted to know for a certainty, if I could, whether it would have a tendency to give the water a taste. It has n't up to this time, although, just before I came away from Lawrence, one lady called me up and said she thought she detected an odor in the water; but as the bed was cleaned as late as the twenty-eighth day of August, I don't think that can be. I simply wanted to know what your opinion would be on that.

MR. C.-E. A. WINSLOW. I could not express an opinion without knowing what the organism is.

MR. COLLINS. I should judge it was about the same growth that we always have in summer, although a year ago the growth was so extensive that we had to scrape the bed in ten days.

MR. C.-E. A. WINSLOW. I ought to say that what I said with reference to river-water, had reference of course to raw river-water. I cannot judge of the efficiency of filtration in the case Mr. Winslow has spoken of.

THE WORK OF SANITARY INSPECTION ON THE METROPOLITAN WATER WORKS.

BY WILLIAM W. LOCKE, SANITARY INSPECTOR, METROPOLITAN WATER WORKS, SOUTH FRAMINGHAM, MASS.

[*Presented September 18, 1901.*]

The public water supplies of cities and towns are derived either from surface supplies or wells. By surface supplies we mean those whose waters are collected from streams and ponds, and stored either in natural or artificial reservoirs for use as needed. If the amount of water needed is large, either the watershed and storage reservoirs must be large or the rainfall abundant. It is manifestly impossible for most cities and towns to own the watersheds from which their supplies are taken so as to exclude all inhabitants from the same, consequently the aim should be to use a watershed with as sparse a population as possible upon it, that the amount of pollution getting into the supply may be a minimum. As the land along most of our large streams is fertile, it is generally kept in a high state of cultivation and is quite densely populated. At every heavy rain large quantities of organic matter may be washed into the streams.

The object in presenting this paper to this Association is to call attention to the dangers constantly menacing the health and well-being of our cities and towns where surface water works are in operation, through the pollution of the sources of supply by house and barn drainage, and to suggest some of the agencies through which such pollution may be prevented. I need only to call attention to the sad experiences of Lowell and Lawrence, where epidemics of typhoid fever have been repeatedly shown to be caused by a polluted water supply, and to the recent epidemic in New Haven, where it was established that the disease was spread by means of the water supply, to convince you that eternal vigilance and the authority to prevent pollution, by the use of stringent measures if necessary, are essential to the well-being of a community.

Perhaps you are not all familiar with the facts relating to the New Haven epidemic, and it may be proper for me to allude to them

here. I am indebted to Dr. Frank W. Wright, health officer of New Haven, for the following statement: —

In the remote limits of an adjoining town, eight miles from New Haven, there had been during the first three months of the year, at different times, three cases of typhoid. The discharges from the patients were not disinfected, but the father of the family was directed to bury them. During the illness of these patients the ground was frozen solid, and there is every reason to believe that there was no true burial of the feces. The alleged place of burial was on a side hill with a steep inclination to a water course leading directly to Dawson Lake, an important reservoir of the New Haven Water Company.

During all the season there had been an unusual absence of rain. On the 11th of March, 1901, however, there was a precipitation of 2.46 inches in twenty-four hours. This heavy fall had a scouring effect upon the surface, carrying all loose débris into the water courses. The temperature had risen during the previous three days so that the surface of the ground was partly thawed, but the deeper ground was still frozen. Doubtless the greater part, or the whole, of the infected material was washed into Dawson Lake by this rain of March 11. The first notice of a marked increase of typhoid was on April 3, twenty-three days after the heavy rainfall of March 11, or on the expiration of the period of incubation. The number of cases reported increased daily until the maximum was reached on April 9, after which there was a gradual decrease until April 15, when the total number of cases reported had reached three hundred and fifty. The persons afflicted were limited very closely to those who were supplied with water from Dawson Lake. No other source of infection was discovered, although the most diligent inquiry was pursued. Many of the students at Yale College were afflicted, and others remained away after the Easter vacation because of the prevailing conditions. Besides the loss of life and impaired physical vigor of the victims, which cannot be reckoned in dollars and cents, the direct financial loss to the city must have been very great.

The city of Boston, through its water board, early recognized the necessity of adopting a vigorous policy to protect the purity of the water. In 1874 a medical commission, consisting of Drs. Charles W. Swan, Edward S. Wood, and H. P. Bowditch, made a very valuable report upon the sanitary qualities of the Sudbury and some other

river-waters. In 1879 Mr. Desmond FitzGerald, then superintendent of the Western Division, made a detailed report to the board showing the number of cases of contamination, and proceedings were begun in the courts against the offenders. But, owing to the uncertain bearing of the law, not much was accomplished until 1885, when the now classic case of Martin *v.* Gleason was decided by the Supreme Court in favor of the city. This decision may be found in the ninth report of the Boston Water Board, page 76. Mr. Gleason was the proprietor of a hotel in Natick, the discharges from sinks and water-closets being conducted by a pipe directly into Pegan Brook, one of the feeders of Lake Cochituate. This decision showed clearly that the city had the right to protect its water supply against pollution as far as the Cochituate watershed was concerned. Mr. FitzGerald's report of that year described ninety-one cases of pollution in Natick, the most of which had been at least partially remedied at the end of the year. Between 1885 and 1889 there were one hundred and thirty-three cases reported in Natick, from which there was direct pollution into Pegan Brook, one hundred and thirteen of which were dwellings or hotels, thirteen were factories, and seven were stables. Although a sewerage system was put into operation in 1896, and every effort short of carrying the cases into court was made, still, out of these original one hundred and thirty-three cases, six were yet unsatisfactory at the beginning of this year, and twenty-one had been only partially remedied by means of cesspools. I have cited the case of Natick to illustrate what is true everywhere throughout the watersheds of the Metropolitan Water Supply, namely, the practical difficulty in the way of persuading people to take care of their wastes. The proper officers should have authority to order and supervise all changes in drainage, and the power to enforce reasonable rules and regulations for the protection of water supplies.

The drainage area of the Sudbury River and Lake Cochituate supplies embraces about ninety-three square miles, upon which there was a total population, according to the census of 1890, of 39 390, or an average of 424 per square mile. The drainage area of the south branch of the Nashua River above Clinton is about one hundred and eighteen square miles, with a total population in 1895 of about 8 160, or 69 per square mile. Although the population of some of the villages upon the Sudbury and Cochituate watersheds has increased since 1890, that of others has decreased, so that the

average per square mile is probably about the same now as then. On the Nashua there has been a material reduction in the population, owing to the removal of houses and factories from the site of the Wachusett Reservoir.

There are several large towns upon these watersheds, where the population is quite dense over small areas, but outside of these centers of population the country is probably no more thickly settled than in the average New England farming community. In towns where there is a public sewerage system, there ought to be no difficulty in getting all houses along the line of the sewer connected with it. This is especially true in Massachusetts, where Chapter 132 of the Acts of 1890, Section 1, reads as follows: "Every building situated on a public or private street, court or passageway, in which there is a public sewer, shall, when required by the board of health of the city or town in which it stands, be connected by a good and sufficient particular drain with such public sewer." This act puts the burden of compelling connections upon the local boards of health, but their labors may be made much less arduous if the town adopting a sewerage system also puts into its by-laws a clause charging sewer rentals. The officers of the town then become interested to keep the tax rate down, by compelling all owners of houses along the lines of the sewer to become users of the same and to bear their proportion of the cost of construction and maintenance.

I am aware that there are not many towns in New England having the watersheds of their surface water supplies within the town limits, or, if such is the case, having a sewer which can be reached. But, as you know, the supply of the Metropolitan Water and Sewerage Board is procured from watersheds located in several towns, and through the local boards of health, acting under the before-mentioned law, we have been able to remedy many cases of pollution. If, in any case, the local authorities should fail to act, under Chapter 488 of the Acts of 1895 the Metropolitan Water and Sewerage Board may enforce the rules and regulations made by the State Board of Health for the sanitary protection of waters used by the water board for the supply of the Metropolitan District. In brief, these rules are as follows: —

No cesspool, privy, or other place for the reception, deposit, or storage of human excrement, and no urinal or water-closet, not discharging into a sewer, shall be located within fifty feet of high-water mark of any lake, pond, reservoir, stream, ditch, water-course, or other open waters used by

the Metropolitan Water Board as a source or for the conveyance, storage, or distribution of its water supply.

No human excrement shall be deposited or discharged in or into such water supply, or shall be kept in or deposited or discharged in or into any cesspool, privy, or other receptacle situated within two hundred and fifty feet of high-water mark of any such waters unless such cesspool, privy, or other receptacle is so constructed that no portion of its contents can escape or be washed into any such waters.

No human excrement, or compost containing human excrement, or contents of any privy or cesspool or sewer, or other receptacle for the reception or storage of human excrement, shall be deposited or discharged upon or into the ground at any place from which any such excrement, compost, or contents, or particles thereof, may flow or be washed or carried into any such waters.

No house slops, sink waste, water which has been used for washing or cooking, or other polluted water, shall be discharged into any such waters, or into the ground within fifty feet, or upon the ground within two hundred and fifty feet of high-water mark of any such waters.

No garbage, manure, or putrescible matter whatsoever shall be put into any such waters, or shall, except in the cultivation and use of the soil in the ordinary methods of agriculture, be put upon the ground within two hundred and fifty feet of high-water mark of any such waters.

No stable, pigsty, henhouse, barnyard, hogyard, hitching or standing place for horses, cattle, or other animals, or other place where animal manure is deposited or accumulates, shall be located, constructed, or maintained, any part of which is within fifty feet of high-water mark of any such waters; and no stable or other place as above enumerated shall be located, constructed, or maintained within two hundred and fifty feet of high-water mark of any such waters unless suitable and adequate provision is made to prevent any manure or other polluting matter from flowing or being washed into such open waters.

No interment shall, except by permission in writing by the Metropolitan Water Board, be made in any cemetery or other place of burial within fifty feet of high-water mark of any such waters.

No manufacturing refuse or waste products or polluting liquid or other substance of a nature poisonous or injurious either to human beings or animals, or other putrescible organic matter whatsoever, shall be discharged directly into, or at any place from which it may flow or be washed or carried into, any such waters.

No person shall bathe in any such waters.

The penalty for the violation of these rules may be a fine of five hundred dollars or imprisonment, not exceeding one year, in the house of correction, or both such fine and imprisonment.

I have not quoted the rules in full, but enough to show that they specify very clearly the various kinds of pollution, and how each case is to be treated.

These rules and regulations do not apply to the water supplies of the other cities and towns of the State; but if local authorities have difficulty in preventing the pollution of their supplies, they may appeal to the State Board of Health, which, under Chapter 510 of the Acts of 1897, has the general supervision of, and authority to examine, all the streams and ponds used by any city, town, or water, or ice company as sources of water supply, together with all springs,

streams, and water courses tributary thereto, with reference to their purity, and to make rules, regulations, and orders for the purpose of preventing pollution and securing the sanitary protection of the same.

. We have usually succeeded in persuading the owner to remedy any defects in the sanitary arrangement of his premises by simply calling his attention to them and explaining what was required; but sometimes we are met by the assertion that he rents his house, and is not responsible for the actions of his tenant. But the Supreme Court has decided that a landlord is liable for the acts of his tenant in polluting the waters of a brook, which is a natural water-course running through the premises, by discharging sink water therein, if the building leased is adapted and intended to be used in the manner complained of, whether he retains control over the house or not. Where an owner will not yield to moral suasion, the local board of health is appealed to if the case can be classed under the head of a nuisance or is dangerous or detrimental to health. In any case there are laws enough in Massachusetts to cover all cases of pollution of a public water supply. Sometimes it requires courage and possible loss of political position to enforce them.

The work done by the sanitary inspector of the Metropolitan Water Works, during the year 1900, is briefly summed up by the Board in its annual report to the legislature, as follows: —

"The watersheds of the various sources of supply have been constantly inspected by the sanitary inspector and his assistant, in order to insure suitable sanitary conditions, and to prevent contamination of the water from infectious diseases. The larger part of the work has been directed to the Sudbury and Cochituate watersheds, but considerable attention has been devoted by the inspector to the Wachusett watershed, partly in assisting the medical inspector, whose attention has been devoted to the works of construction.

"The number of different premises inspected on the Sudbury and Cochituate watersheds has been 1 041. Many cases of objectionable drainage have been prevented, offensive cesspools have been abandoned, the building of sewer connections or cesspools has been required, manufacturing wastes have been diverted from the supply, and in other ways sources of contamination have been removed, so that a marked improvement has been effected in the sanitary condition of the watersheds.

"Endeavor has been made to enforce the statutes of the Common

wealth and the regulations of the State Board of Health prohibiting bathing in all waters which are used for the purpose of domestic water supply."

DISCUSSION.

THE PRESIDENT. Mr. Locke's paper is now open for discussion.

MR. GEORGE E. WINSLOW.* I would like to ask Mr. Locke one question. I was n't here when he began to read his paper, and so I did not hear it all, but I would like to know if boating, fishing, and picnic parties are allowed on the ponds?

MR. LOCKE. Yes; on Lake Cochituate and some of the natural ponds boating and fishing are allowed.

MR. WINSLOW. Is that at all times, or only at certain seasons of the year?

MR. LOCKE. At all times.

MR. WINSLOW. Is that done promiscuously, that is, at anybody's will, or is it done by license from the commissioners or whoever is in charge?

MR. LOCKE. There are certain regulations which people are supposed to observe, and which police officers are appointed to see are enforced, with regard to boating and fishing and the leaving of remains of lunches or dead fish, which tend to pollute the water; but no restriction is put upon people as to boating and fishing at any time or in any place, provided they are reasonably careful.

MR. C. W. SHERMAN.† I would say, in further explanation of that point, that one reason why so much liberty is allowed on Lake Cochituate is that it is one of the "great ponds" of the State, and the public had had rights of that nature in it long before it was taken for a water supply, and those rights have never been curtailed. In the early days it was not thought necessary to pay much attention to these matters, and it has not been considered feasible since to attempt to stop the general use of the lake for boating and fishing. The artificial reservoirs are not used for boating, and they are used for fishing only under license from the board, except at a few specified places, and then under the conditions mentioned by Mr. Locke.

MR. LOCKE. I am asked what area of surface Lake Cochituate has.

MR. SHERMAN. About seven hundred and seventy-five acres.

* Waltham, Mass.

† Assistant Engineer, Metropolitan Water Works.

MR. M. O. LEIGHTON.* The rules read by the author define certain distances from ponds and reservoirs within which certain nuisances are prohibited. Suppose there were nuisances outside of these limits, which was, without doubt, polluting the water, what would be the method of procedure in such cases?

MR. LOCKE. We strive to treat each case by itself so far as possible. It is impossible to make a rule which will apply to every case, but if we are positive that the supply is being polluted, we appeal usually to the local board of health. If that is not sufficient to remedy the evil, then we take the case up ourselves under the regulations against the pollution of water supplies. There is a case at the present time which has been decided in favor of the water board, although as yet the remedy has not been applied, where the pollution originated a quarter of a mile away from the stream. In that particular case, at times of large flow of water, the drainage from the houses goes into the water supply and at other times it does not; but so long as during a certain season of the year, in the spring or at a time of large flow, the man pollutes the supply, he has been held to be subject to the proper remedy.

MR. SHERMAN. There are one or two points which perhaps might be elaborated a little more fully, and it seems to me that it would be interesting if Mr. Locke would give a little further detail concerning them; for example, in relation to the proof that any particular case would be a pollution of the supply, if it became necessary to take a case to the court. Of course there would then have to be adequate legal proof that the waste from any certain premises reached the water supply, and I think a brief statement of the methods employed in obtaining such proof would be of interest to the members.

MR. LOCKE. In cases where the drainage is carried underground by means of pipes, and it is impossible from surface indications to prove conclusively that the drainage comes from a certain house, we usually apply the bluing test. We have some bluing which is especially strong, and this is placed in the sink, or somewhere in the drainage system within the house, in the presence of witnesses, and then water is poured in after it, either from the tap or from the pump, and we watch where we think pollution is likely to come out; and if we get traces of bluing in the water — it is quite a permanent color and is very easily distinguishable even though the quantity be very small — we can be pretty positive where the drainage comes

*Montclair, N. J.

from. Where there are several houses in a row, it is not always easy to tell just where the pollution is coming from, and sometimes it is necessary to put the test on to a number of houses in order to be sure.

MR. A. D. FULLER.* Are there any regular methods of disposal of sewage prescribed or advised in cases of premises which are located out of the reach of a sewer and yet within the watersheds?

MR. LOCKE. No. The best we can do in some cases is to advise cesspools, although we do not advocate cesspools if we can get along without them. But where the soil is gravelly, if the owner will build one cesspool, and then go a little further and build a second one as an overflow from the first, the final effluent will be pretty well purified, and we need not anticipate much danger from it. If the soil is clayey or rocky, the problem is a more difficult one. There are certain large plants, like the Deerfoot Farm in Southboro, and the St. Mark's School, where the drainage is considerable in amount, and in cases of that sort filter beds are built. If gravel is not handy it is brought in, and artificial filter beds built and divided into a number of small areas which are each capable of holding at least one day's flow, and then the sewage is turned from one bed to another. In the case of the Deerfoot Farm there are fifteen beds, and one after another is used until the whole fifteen are covered. In the meantime, the water has filtered away from the first ones, the surface is raked off, and the beds are in condition to take another dose.

MR. SHERMAN. It may not be out of place in this connection to call attention to the fact that when the towns of Natick and Westboro and the city of Marlboro, all of which are situated in or partially in the Sudbury and Cochituate watersheds, put in their sewerage systems, they were encouraged by the city of Boston by the payment of a certain sum, which amounted to a fair percentage of the total cost of the works, towards the construction of the systems, on condition that the sewage should be discharged and disposed of at some point outside of the watersheds.

MR. LEIGHTON. I should like to ask Mr. Locke what is done with the surface drainage from the streets in such a place as Natick.

MR. LOCKE. Pegan Brook, which flows through Natick and receives the drainage of the streets, runs down to a settling basin near Lake Cochituate, which is made by building an embankment across the brook, and the water is pumped from this basin upon filter beds,

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constructed by the Boston Water Board and operated by the Metropolitan Water Board; so it is all filtered before it finally goes into Lake Cochituate. In that particular case the street wash is taken care of in good shape. The same system is used also in Marlboro.

MR. LEIGHTON. Are the systems of sewerage in these towns separate or are they combined?

MR. LOCKE. They are separate systems.

EXPERIENCES IN REDUCING WATER RAM CAUSED BY DIRECT-ACTING PUMPING ENGINES.

BY GEORGE E. WINSLOW, WALTHAM, MASS.

[*Presented September 18, 1901.*]

Mr. President and Gentlemen, — I have not prepared a formal paper on this subject, as I have n't had time to write one, so I will give you in a conversational kind of way a little experience I had with water ram; I don't doubt that many of you have had similar experiences.

In 1872–73 the water works were built in Waltham. The pipe from the pumping station to the reservoir was twelve inches in diameter and 2 700 feet long, and one pump of 1 500 000 gallons daily capacity was put in use. This answered very well for the size of the works. In 1881 another 1 500 000-gallon pump was put in service, and we used the same main; no other main was laid. In due time the amount of water used in the city was so large that one pump would not supply it, and it was necessary to run the second pump also. The friction in the main was so great under those conditions that the pumps could not be run at full speed; they could be run at about three-quarters speed, and then at times the water ram would be enough to jar the pumps pretty severely.

In 1891 we laid another pipe, twenty inches in diameter, to the reservoir, with the idea that it would not only take all the water these two pumps would lift, but that when we put in a larger pump it would also act as a force main for that; and this was found to answer very well.

After the second main was laid, the two pipes were arranged so as to allow the use of either one or both by either of the pumps; but our engineer was very desirous of having them remain separate, and, as a matter of fact, one pump pumped through the twelve-inch main and the other through the twenty-inch.

The next year we increased our supply, by building a well in our receiving basin, carrying it down some eighteen feet below the bottom of the old basin; the water would then be twenty-seven feet deep in the well when at the average level of the water in the river. The old basin

was connected with the pumping station by a conduit, and in the station was a pump well at the same level as the conduit and the basin outside. Both pumps took from this well, with a direct rise and no turn in the pipe, making a short suction. The water, being about nine feet deep, gave us ordinarily a suction of from fifteen to eighteen feet. The pumps ran satisfactorily under those conditions. But when we came to extend the suction to the new well, which we had to do to pump below the level of the old basin, those pipes were about eighty feet in length. These suction pipes were each twelve inches in diameter. We put in the first one, connected the pump and tried it, and found that we could run only fourteen revolutions a minute on account of the water ram. The engineer thought there were leaks in the suction pipe, but we looked it over carefully and found none.

While making the plans for this suction, I conceived the idea that the pumps would n't act satisfactorily without an air chamber on them, and, as a consequence, I had a T made in one of the sections on which I could put an air chamber, but this was some twenty feet away from the pump, and a very poor place for an air chamber. After trying one pump with no air chamber and getting only fourteen revolutions a minute, with a tight suction pipe, I got a piece of six-inch pipe, three feet long, and put it on to this T. This made a small air chamber. The result was that we could run at twenty-two revolutions a minute; so we found that using a small air chamber helped considerably. I then put on a larger air chamber in the same place, and found we could run at twenty-four revolutions a minute. On the other suction pipe was a twelve-inch Chapman valve with the dome up, within seven or eight feet of the pump, which acted as an air chamber. When we started that pump we could get twenty-four revolutions a minute before it commenced to ram. This showed that it would be an advantage to put the air chamber on the cross drum nearer the pump, where both pump cylinders connected, or to get a place for the air cushion as near the pump as possible; that would probably stop the ram. I finally persuaded our commissioners to allow me to do this, and I got an air chamber of the ordinary size, three feet high and a foot in diameter, and applied it to this drum next to the pump.

In order to see what was occurring, I put a water glass on it, and also a vacuum gage. I also connected this air chamber to the condenser of the pump, with an ordinary one-eighth-inch pipe. At first I put that halfway up the air chamber, and it worked well; I thought it might be better to have more air space, so I put it a little lower; and

finally I got it down to about a foot from the bottom of the air chamber. It worked very well indeed, and the pumps could run thirty revolutions a minute, and not do any damage or ramming. In fact, they ran more smoothly than they had ever run.

The reason for putting this pipe into the air chamber was to exhaust the air which would be given up by the suction, and to keep it from getting into the pump proper. I found by shutting off the pipe from the air chamber to the condenser, and watching the glass, that in forty minutes the water would go down 0.1 of a foot, so that there certainly was air being given up by the water. Under those considerations, when the pump was running normally, the pump might, by change of steam pressure, slow one or two revolutions per minute, the water would rise in this air chamber, more air would be given up so it would come down nearly to the bottom of the chamber; then the steam pressure would come up a little, the pumps would increase their speed to correspond, and the consequence would be that some of the air in the air chamber would pass into the pump, and we would get a bang which was disagreeable. By putting the pipe up on the air chamber, it kept the water up in the chamber, so that, if the pump did speed up a little, it would n't give up air, that is, it would n't let the air get into the pumps. Consequently, the pump ran smoothly at all times.

On the suction pipe close by the pump was a pet cock, with a hole perhaps a tenth of an inch in diameter; when the ram came, water would spurt out of that cock at the end of the stroke so that it would strike the other pump, probably ten feet away, and then air would be drawn in. The air chamber relieved that shock. Then the question arose, What produced this shock and how could it be overcome?

Afterwards I thought, and I think now, that the action of the direct-acting pumping engine is not what it should be, for the very reason that a full head of steam is given to the ordinary direct-acting engine for the full length of its stroke, and the valves are operated by the opposite piston from that which is doing the work. The piston comes nearly to the end of its stroke, and then comes against the steam cushion, which is regulated by the compression valves; and the consequence is that, as the piston moves from one end to the other, it maintains the same speed out to about the point where it begins to compress the steam cushion and then stops in a very short distance, and that produces a very heavy ram. If a man were to let water out of a main pipe at the rate that it is being moved by the

pump, and were to stop it in the short space of time in which the piston is stopped, he would be likely to break something.

I have asked a number of engineers who are running pumps what the consequence would be if they could shut off the steam at the end of the stroke and prevent the piston head from coming against the cushion with so much force, but cut the steam down so that the piston would come to a stop of itself without compressing the steam cushion, — perhaps have no steam cushion at all, but let the water that was being pumped stop the piston; and, in most cases, the answer has been, "If you want to run a direct-acting pumping engine you have got to give steam the whole length of the stroke, and that is all there is to it."

Now, I have found that there is something more than giving steam the whole length of the stroke, and I have experimented to see what would happen if steam were cut off; and I find that an engine can be run without using the steam cushion, by shutting off the steam gradually towards the end of the stroke so that when the piston gets to the desired point there is no steam coming into the cylinder, and the piston stops because there is no force to push it against the water. In other words, let the water which is being forced become the cushion; and, by cutting off steam at the point desired, you have a very smooth stroke, and one which does not produce any ram.

Now I don't say that you want to cut off the steam at one half the stroke or commence to shut it off there. You want to shut it off at the point desired, and correspondingly let steam into the opposite cylinder. That is something which will have to be determined by experiment for each case, on account of the different length of strokes of different pumps. I tried my experiments on a small boiler feed pump, and I will give you a little idea of them.

The pump I used was a $4 \times 2\frac{3}{4} \times 4\frac{1}{2}$ inch, in other words, the water end was $2\frac{3}{4}$ inches in diameter. I arranged it so that it ran very smoothly, pumping out of a barrel and back into the barrel, contracting my discharge so as to get the pressure desired. It was a standard pump, well made, by a company which understands its business, and it does good work. At first the pump pressure varied from seven and one half to eight pounds on every stroke, running against fifty pounds pressure. That was the best I could do with it. I put on my attachment and got it to a point where the variation was less than one half a pound on any stroke. I then tried it in different forms to see if I could make the piston strike the cylinder head. With the old

attachment on, I had no trouble at all in making it strike the head, as you have seen many pumps do on water works when you suddenly open up a main or a hydrant. It compresses the steam cushion, the steam behind is pressing just as hard, and the resistance of the water is reduced, and perhaps the piston strikes the steam cushion hard enough to knock the head out.

In the ordinary pump one piston wholly controls the valves of the other piston, and after it has made a stroke the valve remains open until the piston of the other pump closes it. In this case I arranged so that when the piston approached the end of the stroke it shut off its own steam without regard to the motion of the piston which gave it steam and, as a consequence, it stopped easily.

To show you how that worked, I put the old valve motion upon the pump, and I opened the valve with one hundred and five pounds of steam at the boilers — I cannot say just how much there was at the pump for I did n't put on a gage, but the loss was small — and it ran four hundred and ninety-six strokes a minute, or one hundred and twenty-four revolutions; and within three minutes the pump had jumped about four inches along the bench, and would have gone farther if it had n't been prevented. The plunger went against the heads very hard, and I did n't dare run it any longer for fear I would break the pump. I then put on this experimental valve motion and tried that. I wanted to give it just as good a chance as I did the other to run away if it could, so I put a mark on the bench to see how much the pump moved, turned on a full head of steam, and let it go. I ran it for five minutes; it made five hundred and twenty strokes a minute, or one hundred and thirty revolutions. I arranged my valve motion so as to cut off the steam before the piston got to the steam cushion. It ran very smoothly, and during the whole time it made no more noise than under ordinary conditions, and there was no jar whatever. It did n't move enough on the bench so that I could measure it. It was running considerably faster than with the old motion, and running as quietly as at the ordinary fifty strokes, while just before, with the old valve gear, it had been threshing itself to pieces.

I found also that I could take the suction out of the water, with a full head of steam on, and let it run away, and, even under those conditions, the plunger would not strike the heads, but the stroke would be a little shorter. That is something most people do not credit until they see it.

I then concluded that here was something which would be of value for people to know; not perhaps that my device will ever be used, but I do rather think the idea will be used, because it not only insures safety, but I think it is also economical; for when the stroke is completed the steam is shut off, the ram is prevented, and there is no danger of the piston running against the head and knocking it out. It shuts off the steam at the end of the stroke, and if the piston goes at all beyond the point desired it opens up its own valve, from the other side, discharging the steam which is pushing it, and giving steam from the boiler to overcome the momentum of the piston.

It is something I would like to have anybody see who is interested in it. I am not in a position to build any of them; I have n't got the shop or the money to do it with, but I wanted to speak of it on account of its stopping the ram. And another thing: I think the speed of an ordinary pump, running at thirty-five or forty revolutions a minute, can be increased to fifty revolutions. In other words, you can get a larger amount of water out of the same pump by running faster, with perfect safety. You are going to save a portion of the steam which is used to push the plunger against a heavy pressure, and you are going to get an increased duty out of the pump in other ways, and this is in addition to the safety feature of it. Some members of the Association have seen it, and a great many other men who are not present. As I have said, I have no written paper on the subject, and perhaps I have not given as many details in regard to the matter as I should if I had had time to prepare a paper.

DISCUSSION.

MR. F. N. CONNET.* If I understood Mr. Winslow's description, his device is intended to allow a direct-acting duplex pump to work in this manner: The inlet valve for the right-hand cylinder shall be opened by the left-hand cylinder, and the steam shall be cut off by the movement of the right-hand cylinder, and *vice versa*. If that is the device, I would say that the same thing has been exhibited by the Worthington pump people in Brooklyn. Some three or four years ago I saw some new vertical pumps in the Ridgeway pumping station, in which exactly that device was used, and I think the reason for using it was to accomplish the same ends that Mr. Winslow has described.

MR. WINSLOW. I will allow that the gentleman is partly correct in what he says, but not wholly. After doing what I did in the mat-

* Engineer, Builders' Iron Foundry.

ter, I thought I would protect myself, so I applied for letters patent and obtained them. In doing so I found I had run against not only Worthington but Gaskill and a man named Clark, in Northampton, but none of them has the same device. In each of those, not only the Worthington but the Gaskill and the Clark, the right-hand valve, which gives steam to the right-hand cylinder, is opened by the left-hand piston, and, when it gets to the end of the stroke, it is closed in part by the action of its own piston and in part by the action of the opposite piston; and on that account there is a failure to accomplish the object I have been after. What I wanted to do was to get a stroke that was always of the same length. Now, in the Worthington, the Gaskill, and the Clark devices, each valve is operated by the action of both pistons, and the consequence is you get a variable length of stroke, and you cannot depend upon it, but you have to use a steam cushion as before. With my device, the right-hand piston opens the valve giving steam to the left-hand piston, and in making its stroke the latter disconnects the valve from the right-hand piston so that, when it gets to the part of the stroke desired, it shuts off the steam independently of the motion of the piston that gave the steam, and *vice versa*. Cutting off the steam independently of the piston that gave it is something that the others do not do. A representative of the International Steam Pump Company called, the other day, and he saw that the device did what I told him it would do. I told him that the longest stroke that the piston would make would be at the time it was doing the most work, that is, when working against the heaviest pressure of water. Now, if the pressure is released by opening a hydrant, breaking a main, or by any other accidental or natural cause, instead of increasing the length of the stroke it shortens it a trifle. In the other devices the stroke could not shorten, but it would lengthen the same as in the ordinary direct-acting pump and possibly do damage.

I would say in addition, although I don't know but I have said it already, that the hardest test I put it to was to unscrew the suction and open up the discharge, and let on a full head of steam and let it run. It ran over twelve hundred strokes a minute, and the stroke was not so long under those conditions as it was in the ordinary operation of the pump. That is something this representative of whom I spoke was a little surprised at, because when I told him sometime ago it would do that, he replied, "If it will, it will do something different from any pump I ever saw."

THE POLLUTION OF STREAMS BY MANUFACTURAL WASTES, AND METHODS OF PREVENTION.

BY H. W. CLARK, CHEMIST, STATE BOARD OF HEALTH OF MASSACHUSETTS.

[*Read November 13, 1901.*]

The question of the pollution of streams and the purification of sewage and manufactural wastes early received the attention of the State Board of Health. After the establishment of the board in 1870, mention of these matters was made in each report, and there is included in the annual report for 1876, a special report upon this subject, as a result of an investigation ordered by the legislature of 1875. This report covers four hundred pages, and it is divided into four parts. The first, upon the pollution of rivers, is a report of an investigation carried on by that noted engineer, James P. Kirkwood, and one of the sub-reports upon the disposal of sewage is by Charles F. Folsom, M.D., at that time secretary of the board, who traveled extensively abroad to collect the data there given. Mr. Kirkwood's report is a general review of the nature of the polluting liquors from various industrial works and cities and towns, together with a statement in regard to the condition of several of the watersheds of the state. In his summary he states that,

"the law under which the investigation was carried on requires the Board of Health to devise a system by which such rivers, estuaries, and ponds may be protected against pollution so far as possible, with a view to the preservation of health of the inhabitants of this commonwealth."

But he adds,

"that to devise and perfect a system as varied in its modes of action as the fluid impurities emanating from the different kinds of works and from ordinary sewage will require, must, as has been hinted above, be a work of time; and while authority must be lodged somewhere to begin this work, it seems obvious that the authority given should, in fairness to cities and manufactories, be exercised at first only conditionally, and that in the case of any fluid impurities requiring to be stopped from entering the stream and to have their poisonous qualities destroyed and the residue rendered innocuous before being passed into the stream, the authority having the power to require this course should be required to show how it can be done and the apparatus and material required to effect it."

At the time this report was written, although forty-eight cities and towns of the state, with an aggregate population of nine hundred and

seventy thousand people, had introduced partial or complete water supplies, only twenty-four had provided even partially for the proper removal by sewers of such large quantities of water as this implied. It is apparent, moreover, to any one who reads Mr. Kirkwood's report that to him at that time the main question in regard to the prevention of the pollution of streams was how to prevent the wastes from large manufacturing establishments scattered all over the state from entering the streams except after, at least, partial purification. In the period of twelve years, however, elapsing between the time of writing that report and the time of establishing the Lawrence experiment station, the number of cities and towns which were sewered increased rapidly, so that, when the board began to study the question of sewage purification in a systematic way at the station, established for that purpose as the result of an act of the legislature, its first investigations were directed almost entirely to the disposal of domestic sewage. From January, 1888, when the work of the board along this line was begun, up to the close of 1894, a period of seven years, the disposal or purification of manufactural wastes was hardly mentioned in its reports, and the disposal and purification of these wastes really seemed at that time of minor importance, not because their careful and scientific purification is not desirable, and is not eventually necessary if the dwellers along many of our streams and rivers are to live in health and comfort, but because the first — the disposal of domestic sewage — is the larger question in which all members of many communities are directly interested and for which they are all in a sense directly responsible.

Beginning in 1895, however, and continuing almost uninterruptedly to the present time, a succession of interesting and practical investigations upon methods of purifying manufactural wastes have been carried on by us, and the results of these investigations have been given partially in the various annual reports of the board and, also, in at least two special reports upon investigations in regard to the pollution of two of the rivers of the state. To those who have studied the rivers and small streams within our state, it is evident that there is a number of the smaller rivers, such as the Neponset, the Sudbury, the Assabet, the Nashua, the French, the Hoosick, Crane's River, and others, which are at places, or along practically their entire course, foully polluted by waste liquors from various manufacturing plants. Some of the large rivers, such as the Merrimac, moreover, are receiving immense quantities of manufactural

wastes, together with domestic sewage, and their waters are prevented only by reason of their volume from becoming as foul in appearance and character as the waters in some of the smaller streams. It is the natural result of the development of the water power of the state, and it is equally as natural that, sooner or later, the people of the state will demand such a cleaning up of the rivers now polluted from these wastes as can reasonably be required or demanded of the corporations or individuals responsible. It is also apparent to one who has looked over these rivers that the principal manufactural pollutions are from woolen mills, paper mills, and tanneries. Other industries cause much pollution in places, but they are not so widespread.

If we take the Neponset River, for example, we find that the manufactural wastes entering its upper portion are largely from paper mills. As it passes through Norwood it receives the wastes from large tanneries, and as it emerges from the Fowl Meadows, at Hyde Park, it receives there and at other places farther along its course the wastes from woolen mills and paper mills. The principal manufactural wastes entering the north branch of the Nashua River are from paper mills and woolen mills; the principal manufactural pollutions entering the French River are from woolen mills; the principal manufactural pollutions entering the Assabet and Sudbury rivers are from woolen mills; and those small streams, Crane's River and the North River at Danvers and Salem, receive the waste liquors from many tanneries. It was natural, therefore, that our first investigations upon the purification or utilization of the wastes from industrial works should be confined to the liquors running to waste from these three industries.

WASTES FROM WOOLEN MILLS.

The principal waste liquors from woolen mills that enter into this subject are those caused by the scouring and rinsing of wool in preparation for its manufacture, together with the waste liquor, in some instances, from washing the cloth after manufacture. They are, perhaps, considering their volume in some places and their composition, the most serious mill pollution in the state. This is so both on account of the large amount of organic matter present in them and the extreme difficulty with which this matter is decomposed or changed by bacterial action. Beginning in 1895, the wastes from quite a number of woolen mills have since been studied by us, and

the results given generally in our regular reports, but occasionally in special reports.

It is not an uncommon thing for wool to shrink sixty or seventy per cent. in weight during the scouring and washing process, and this dirt, fat, etc., removed, together with the soap or other chemicals used in the process, give an extremely dense waste liquor. Domestic sewage contains ordinarily from 50 to 150 parts of solid matter per 100 000 parts, or approximately from 50 to 150 pounds of solid matter in each 12 000 gallons of sewage. The solids in the wool liquors that we have examined, however, average about 2 500 parts per 100 000, that is, the liquors have 2 500 pounds of solid matter in each 12 000 gallons of liquid. In some investigations that I made concerning the character and nature of wool-scouring liquors running to waste from certain mills, I found that one mill, discharging about 67 000 gallons of the liquor per day, discharged about 12 000 pounds per day of solid matter. In a second mill, where the scouring was more concentrated, — that is, carried on with a less volume of water, — the solid matter discharged amounted to 7 500 pounds for each 12 000 gallons of wool liquor. These are not selected cases, moreover, but fairly good illustrations of the character, in this respect, of the wool-scouring liquors discharged from many of our woolen mills.

We found early in this class of investigations, during 1895–1896, that it was impossible to cause this liquor to nitrify when passing through intermittent sand filters, unless a certain volume of domestic sewage was added to it; but we found that, if the volume of domestic sewage was very large in comparison with the volume of waste liquor, nitrification would occur and good results be obtained. As an illustration of this work, I can say that in September, 1898, two filters in operation at the Lawrence experiment station, to which we had applied for some years a mixture of waste liquors from Lawrence wool-washing establishments and domestic sewage, were put into operation, receiving a mixture of domestic sewage and the waste from the wool scouring carried on at the Bigelow Carpet Works at Clinton. This investigation was begun because it was evident that this particular waste liquor would have to be disposed of upon the Clinton sewage filtration area, at that time being constructed by the Metropolitan Water Board. These two filters were continued in operation a year and a half, receiving this waste, and were both constructed of sand of an effective size, similar to much of that in the

area to be used, the proportion of the mixture in the beginning of the operation being one part wool liquor to seventeen parts sewage. Early in 1899 this proportion was changed to one part wool liquor to about eleven parts sewage. The average analysis of many samples of this waste liquor gave about the following results: —

(Parts per 100 000.)

Ammonia.			
Free.	Albuminoid.	Oxygen Consumed.	Bacteria per c. c.
6.20	6.62	79.00	3 000 000

This waste, moreover, besides containing the large amount of organic matter and fats, etc., shown by the determinations of albuminoid ammonia and oxygen consumed, contained a very large amount of fine dirt and sand washed from the wool, this, of course, settling quite easily. This sediment, on analysis, was shown to contain at different times from sixty to ninety per cent. of a very fine sand, and the remainder, or from ten to forty per cent., was organic matter. The two filters were kept in operation a year and a half, and during all that time the mixture was applied directly to one, but before being applied to the other it was first passed through a small septic tank. Good purification results were obtained, the nitrates being high in the effluent of each and the unoxidized organic matter comparatively small in amount; but the filter receiving the mixture which had first passed through the septic tank undoubtedly gave the better results and was freer from clogging at the end of the experiment.

Early last year the board was ordered to make a special investigation in regard to "the sanitary condition of the beds, shores, waters, etc., of the Sudbury and Concord rivers," and "to ascertain whether any danger to the public health exists in said rivers or meadows by reason of stagnant water or of refuse from factories or from other causes; and, if they find that such dangers exist, they shall report to the next general court some plan for its removal." The general results of that investigation are found in House Document No. 1 380 of the last legislature, in which is a report upon an investigation that was made in regard to the disposal of manufactural wastes from mills at Saxonville, these being woolen mills and passing their waste liquors directly into the Sudbury River at that point.

We found from measurements of the liquors run to waste from these mills that about seventy per cent. of the volume was from the processes of scouring and rinsing wool, and that about twenty-three per cent. was waste dye liquor. Many experiments were made with this, as with other wool-scouring liquors in previous years, as to the effect of chemicals in coagulating and removing the organic matter present, but, as in previous years, with quite unsatisfactory results. In all, ten different precipitants were experimented with, either alone or in combination, and we found that an enormous amount of precipitant was needed to cause any coagulation whatever. The failure of these precipitants to cause satisfactory coagulation or precipitation was due to a number of reasons. Of course, as the amount of organic matter present in this waste wool liquor is always much greater than that in ordinary sewage, volume for volume, we should expect to be obliged to use much larger amounts of precipitants. Besides this reason, however, much of the fatty matter in the wool liquor is in a state of semi-emulsion as it runs from the drains in the mills, and is of a specific gravity less than that of water, and any coagulation tends to gather much of this matter in masses that contain a smaller percentage of water than before coagulation. This coagulum, therefore, has considerable buoyancy, and tends to carry some of the precipitants to the surface instead of the precipitants carrying the organic matter down, and this buoyancy is only overcome by an enormous amount of precipitants.

It may be mentioned in passing that in Bradford, England, the center of the English woolen trade, where it is calculated that eight per cent. of the sewage of the city comes from wool-washing establishments, it has been shown by experiment that from nine to twelve times as much precipitant is needed when treating week-day sewage as when treating Sunday sewage free from this waste.

As a result of these experiments, the board advised what it has advised in other cases, that the waste liquors from these mills should be mixed with the domestic sewage of the town and disposed of upon the town filtration area. In this connection it is interesting, and, I think, apparent to any one who has visited the Clinton disposal area from time to time and carefully watched the results of filtration there obtained, that the area seems to gather power to more efficiently purify this liquor after it has been applied to it for some time; that is, the bacteria present in the area seem to become, after a time, more and more equal to the task of breaking up even the stable

organic matters in wool liquor and causing them to undergo bacterial oxidation.

I understand from good authority that in England at the presen time, after long-continued struggles with waste wool-scouring liquor at their town and city precipitation and disposal works, those in charge of these works are now taking the ground that this liquor should not be considered as sewage in any sense and allowed to enter the sewers, until the manufacturers themselves have removed from it a very large proportion of the fat and dirt. Collecting this liquid in stone-lined pits, treating with acid, and collecting and selling the fats saved has long been carried on by certain English French, and Belgian manufacturers, presumably with profit. In America there are a few mills where this has been tried, but not with altogether successful results. Other and more scientific methods of saving the fats and carbonates now going to waste are now being tried in many places abroad, but progress along this line in this country is made but slowly.

TANNERY WASTES.

When, in 1895, the legislature ordered the State Board of Health to investigate the condition of the Neponset River and make recommendations in regard to improving it, we began to study the purification of the waste liquors from the tanneries along this river, engaged in tanning sheepskins, filters being put in operation both at the tanneries and at the experiment station. As a result of these studies it was found that there was no difficulty whatever in purifying this tannery waste by intermittent sand filtration. The sewage of tanneries, as many of you have noted, is a very strong, offensive liquor, highly charged with decaying animal tissues, the bran that is added to cause fermentation to take place in certain tanks, and various chemicals used in preparing, tanning, and preserving the hides. It is also at times highly colored by the different dyes used in coloring the hides, and the spent tan liquor. In spite of this general mixture, however, of organic matter, chemicals, etc., the filters operated by us along the Neponset and at the experiment station for two or three years, beginning in the fall of 1895, showed exceedingly good results. One sand filter, containing four feet in depth of sand, to which this tannery sewage was applied at rates of from 30 000 to 120 000 gallons per acre daily, gave a fairly clear, almost odorless

liquid, without much color and well nitrified; during several months of its period of operation the nitrates reaching 8.00, 10.00, and even 12.00 parts per 100 000.

In 1896, experiments were begun upon the purification of the sewage of a tannery in another portion of the state, engaged in preparing and tanning calfskins. These skins were largely imported, and, to prevent decomposition in transit, were packed in a germicide which was present in the sewage throughout the period of experiment. To aid in the process of freeing the skins of hair at this tannery, a ton or more of sulphide of arsenic was used each month, mixed with lime to form a soluble salt of arsenic, and, as a result, the waste liquor flowing from the tannery always contained arsenic in suspension and in solution. Various other chemicals and dyes were used in the tannery, these dyes being generally bright scarlets and crimsons, used in coloring leather to be made up into the so-called wine-colored shoes. Owing to the germicides used, the sewage as it flowed from the tannery was often sterile, and when not sterile the number of bacteria was very small. A considerable portion of the arsenic was held by the organic matter in suspension, however, and was carried down with this matter when the sewage was allowed to stand for sedimentation to take place, enough often being left in solution, however, to impede bacterial growth. It may be mentioned here, to show the volume of waste liquors from manufacturing plants, that the volume from this single tannery, measured upon several different days, showed an average of two hundred thousand gallons flow in ten hours, and by analysis it was proved to contain twice as much nitrogenous organic matter as is generally present in ordinary domestic sewage, and many times as much carbonaceous matter. By experiments, however, it was found that, although this sewage would not nitrify in filters if applied directly, yet if it was first passed through a coke breeze strainer or over iron filings, the arsenic present in it would unite with the iron, and the resulting liquor would be of such a character that it could be easily purified upon intermittent sand filters. A sand filter four and one-half feet in depth was operated for some months at the rate of one hundred thousand gallons per acre daily, and produced an effluent containing large amounts of nitrates and low in organic matters. It was especially noticeable that the sewage, although often nearly sterile before passing to the small preliminary strainer or filter of coke or iron, showed abundant bacterial growth when it

appeared as an effluent from this strainer before passing to the sand filter.

In continuation of our studies of tannery sewage, we last year operated filters with the waste liquors from a tannery where much wool scouring is carried on, and where this liquor, already described, is mixed with the other liquors from the tannery. In this case, as was expected, the mixture was easily acted upon by the bacteria in the sand filters used, the easily decomposable tannery liquors entirely overcoming the stable organic pollutions in the wool liquor, and good nitrification and purification occurred.

WASTES FROM PAPER MILLS.

The waste liquors from paper mills vary very greatly in character and volume, according to the particular class of work done. Speaking generally, they contain a large amount of slowly decomposable organic matter, such as cellulose, and a small amount of easily decomposable nitrogenous organic matter. They are only difficult to handle because of their volume, and when mixed with fair volumes of domestic sewage are easily purified. In investigations that we have made, however, with these wastes from a number of mills, it has been found that generally, if collected and passed through a coke or cinder strainer, even at rates as great as one million gallons or more per acre daily, the resultant effluent is of fairly good quality, and the polluting matters in the liquors, being largely in suspension, are caught at the surface of the strainer, and form an easily removed felt-like mat, which may be disposed of by burning.

WASTES FROM SILK MILLS.

During the present year I have had an opportunity to study and experiment upon the disposal or purification of the waste liquors flowing from a silk mill. The volume of sewage or waste liquor flowing from this mill daily approximates 2 500 000 gallons, and this liquor varies in character very much during different periods of the day on account of the varying processes carried on in the mill, at one time resembling in appearance domestic sewage and then quickly changing to a bright blue, pink, crimson, or other color, due to the discharge of waste dye liquors; these dye liquors coloring the sewage to such an extent that it is, at times, nearly as highly colored as the dyes in the dye vats.

Besides this coloring matter, a very large and varied assortment of chemicals, etc., is used daily in the mill, a list too long to be enumerated here; but, for an example of the kind and quantity, I will name a few, and the average daily amount of each used.

	Pounds.
Carbonate of soda	124
Silicate of soda	147
Ammonia	52
Sulphuric acid	173
Acetic acid	181
Nitrate of iron	339
Bichloride of tin	237
Sulphate of alumina	60
Sodium phosphate	235
Glauber's salt	88
Chloride of lime	186
Logwood	80
Dextrine	1 307
Vegetable gum	91
Aniline dyes	156
Soap	2 000
Muriatic acid	115
Silk gum, etc., worked off the raw silk and entering the sewage	1 520

The list prepared by the mill people showed approximately fifty different substances.

It was found upon experiment that the surfaces of sand filters became quite quickly clogged when this liquor was applied to them, and it was also found that the chief clogging was caused by the starch, dextrine, soap, silk gum, etc., in the sewage. Experiments were therefore made to determine methods of preliminary treatment of the sewage before application to the sand filters, and three methods were tried; namely, a septic tank, a coke strainer, and a contact filter. After a preliminary experiment, which showed that the clogging matters could be removed by each of these processes, good-sized experimental tanks and filters were put in operation at the mill.

The septic tank and accompanying sand filter were of such size and capacity that the sewage applied to the septic tank was twenty-four hours in passing through, and the rate of filtration of the sand filter receiving this sewage was 200 000 gallons per acre daily. The coke strainer was operated at first at the rate of 1 200 000 gallons

per acre daily, and the contact filter at the rate of 1 350 000 gallons per acre daily, these rates afterwards being nearly doubled. The rates upon the sand filters receiving the sewage from the coke strainer and from the contact filter varied from 150 000 to 225 000 gallons per acre daily.

As a result of these experiments it was found that the coke strainer was the most efficient in removing the clogging matters of the silk liquor, that is, it removed nearly 75 per cent. of these matters; the septic tank removed 50 per cent., and the contact filter about 40 per cent. In each case the resulting liquor, when applied to sand filters at the rate stated, was in good condition for purification by sand filtration, active nitrification in the filters ensuing, and their effluents in each instance being generally quite low in color, notwithstanding the bright colors at times of the sewage applied. Notwithstanding the large and varied amount of chemicals allowed to run to waste from the silk mill, the sewage was never sterile, but contained generally upwards of 3 000 000 bacteria per cubic centimeter.

While our main investigations with wastes from industrial works have been with liquors from the classes of mills mentioned, investigations have also been made upon the purification of wastes from creameries, glue works, etc., with favorable results. It must be remembered, moreover, that work of this class is carried on with considerable difficulty and inconvenience. Very often we cannot do it satisfactorily except directly at the works producing the liquor to be investigated, and, while we always welcome such opportunities, they are comparatively few in number.

DISCUSSION.

PROF. LEONARD P. KINNICUTT.* I think the Association is to be congratulated upon having Mr. Clark give to us the results of the careful experiments that have been made, under his direction, in the treatment of trade refuse. I certainly agree with him that nearly all kinds of trade refuse can be purified by bacterial treatment after dilution with domestic sewage. The question is, however, the amount of dilution necessary. This, I believe, must depend on the character of the trade refuse, and that a dilution that would be sufficient

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for refuse from tanneries and breweries would not be sufficient for wool washings, or the refuse from the preparation of wood pulp. When sufficient dilution can be obtained, undoubtedly purification by intermittent filtration is the best and cheapest method. In all cases, however, the preliminary removal of the greater part of the insoluble substances is desirable, which can be done in certain cases, as Mr. Clark has said, by roughing filters run at a very high rate, in other cases by use of the septic tank, and in certain cases by special diverse means, as copper sieves or very careful screening.

It is often very difficult, however, when manufacturing waste in very large quantities enters the sewers, to obtain good effluents by bacterial methods alone; as, for instance, in Worcester, where the sewage as it comes to the works contains from 20 to 30 parts copperas and free acid, equal to 10 parts of pure sulphuric acid in 100 000 parts of the sewage; or at Bradford, England, where the sewage contains over 400 parts of grease to the 100 000 parts.

In these cases, if the sewage, after passing through subsidence tanks to remove a part of the insoluble substance, is run upon beds, the purification is far from what is to be desired, and the beds comparatively quickly become clogged.

In a good many cases, however, there is no question that the sewage of a town, containing comparatively large quantities of trade refuse, can be satisfactorily purified by the combined action of the septic tank and intermittent filtration.

I think there is no question, however, that domestic sewage lends itself more easily to bacterial treatment than sewage containing manufacturing waste, and it is desirable to keep these products as far as possible from entering the sewers. I do not mean to say that it is by any means always the best policy to say to a manufacturer, "You must remove obnoxious impurities from your waste water before you can empty it into the sewers"; only that, if the manufacturer can be induced to do so, it much simplifies the treatment of the town or city sewage.

In England there is an attempt to prohibit obnoxious waste trade products from entering the sewers. The general law of the Rivers Pollution and Prevention Act prohibits the discharging into the sewers of solid matter that may have accumulated in subsidence tanks, but allows liquids to be so discharged, if they contain no injurious or poisonous substances.

The West Riding Pollution Commission excludes all liquids rendered poisonous, noxious, or polluted by manufacturing waste.

The City of Bradford Act declares it is not lawful for any person to suffer any refuse from any manufacturing process that would interfere with the treatment or utilization of the sewage of the city, to flow or pass into any sewer. I might say, however, at the time of my last visit to Bradford, in September, 1901, there seemed to be not the slightest attempt to enforce the law.

The London County Council prohibits the discharge of dangerous substances, especially petroleum products or residues, into the sewers.

These laws have, to a certain extent, caused the manufacturers to partially purify waste products before allowing them to pass into the sewers; but the real reason why more attention has been paid to this subject in England than in this country is that a large number of factories are found on small streams, away from sewer connections, and it is absolutely necessary that the waste products from these factories should be treated before passing into the stream.

A most interesting and instructive paper on this subject by R. A. Tatton and W. O. E. Meade-King, with the discussion that followed, is to be found in the Proceedings of The Institute of Civil Engineers, January 9, 1900. This paper takes up the treatment of the waste products from bleacheries, woolen, silk, and cotton mills, tanneries, breweries, print works, chemical works, etc. The conclusions to be drawn from the paper are, that in most cases, with the possible exception of tanneries and breweries, the waste products should receive chemical treatment before being allowed to run into bacterial beds.

During my visit of last summer to England, I studied the treatment of waste trade products, especially as regards the treatment of liquids containing wool washings and dye stuffs.

Bradford is one of the centers of the woolen trade in England, and over three hundred and seventy tons of wool are washed daily in that district. A large proportion of these washings pass untreated into the sewers, and the city authorities have as yet not found any satisfactory way of treating the sewage. The method now used, of adding sulphuric acid and passing the sewage into subsidence tanks, is very far from being efficient, and various experiments with bacterial treatment have not showed encouraging results. Various firms in the district have, however, attempted treatment of the washings before allowing them to enter into the sewer. The most efficient of these processes is that employed by John Smith & Sons, at the Field

Head Mill. The amount of water used is about one gallon to one pound of wool. These washings, which contain about two per cent. of grease, are evaporated in a Yaryam evaporator, and the grease in the concentrated liquor is removed by centrifugals. The liquid, after the grease is removed, is further concentrated and then, in a semi-solid state, run into a revolving furnace, where the organic matter that it contains is burned; and the residue, containing a considerable per cent. of potassium carbonate, is used in the manufacture of soap. By this process about eighty per cent. of the water used in the washing of the wool is recovered. This water is free from organic matter, and, containing a little ammonia, is much better than city water for washing purposes. It is also claimed that the price of the grease recovered far more than pays for the cost of treatment.

The method usually employed by the manufacturers at Bradford is to add sulphuric acid to the washings, thus cracking the grease, and passing the liquor through filters; in this way, about three fourths of the grease is recovered. The effluent contains about sixty grains of grease to the gallon.

A better method used at one or two mills is to add, besides sulphuric acid, ferric sulphate. It is claimed that the effluent from this process contains not over ten grains of grease to the gallon.

I have already occupied too much of your time, but on some other occasion may speak of the treatment of waste products from other industries, and especially refer to one large print works, where the soap liquors, the logwood liquors, and the liquor from the indigo vat, are all treated separately by chemicals, and the effluent from these processes, after being united with the liquors from the dye house, is treated on bacterial beds.

WATER SUPPLIES OF VERMONT.

BY CHARLES P. MOAT, CHEMIST, VERMONT STATE LABORATORY OF HYGIENE, BURLINGTON, VT.

[*Read November 13, 1901.*]

The State of Vermont, with its Green Mountain range extending throughout its whole length, with its many hills, its numerous streams, lakes, and ponds, together with its small population, living in many towns and villages rather than large cities, is not surpassed by any state in its natural facilities for pure water supplies. Nature has done much for the state in providing such an opportunity for safe water. Still, owing to carelessness or thoughtlessness, many of these beautiful sources have been contaminated, thus endangering other communities farther down these same streams and dependent on them for their drinking water.

Vermont differs from many of our states in being so largely made up of towns — with only six cities, the largest of which has a population of less than twenty thousand. This probably accounts for the numerous so-called public water supplies in each village, and for the few owned by the villages themselves. Most of the villages and cities are supplied by several different systems, each furnishing water to a number of families, besides the numerous domestic wells.

Since the Laboratory of Hygiene was established, in 1899, the waters of the villages and cities having the so-called public supplies, as distinct from those depending on private springs and wells, have been analyzed as often as could be done, with the result that many of these towns and cities are now trying in every way to provide safe water for their inhabitants, and to keep it safe by inspection of the sources and the surrounding country from which the supply is derived. This inspection, which we are urging them to undertake, will bring about a great change in many cases.

Although our data is not by any means as complete as I would wish, I will try and give a brief idea of the kind and quality of the water used by these public systems. No regular systematic investigation has been undertaken on any of these, further than the analy-

ses of samples at intervals more or less frequent, depending on the quality of the water and on the desire of the village or city. I shall take up the villages and cities in each county, beginning with those on the north, and following down to those on the Massachusetts line, giving a brief idea of the water used by the cities and larger villages in those counties, with an average chemical analysis of some of the larger supplies.

Grand Isle, the northwestern county of the state, comprising the large islands in Lake Champlain, depends on the lake and on private wells for its water, and has no public systems.

In *Franklin County*, the next on the northern line, Enosburg Falls and Swanton get their water from the Missisquoi River, a stream rising in the Green Mountains and flowing through northern Vermont and Canada to Lake Champlain; at Swanton, a brook showing evidences of contamination enters the stream and at times pollutes it badly. Enosburg Falls is also supplied with spring water of the Kendall system. Richford, in the same county, uses water from mountain brooks, while Bakersfield is supplied by springs. The range of the most significant constituents* of these waters is as follows, in parts per 100 000: —

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Enosburg Falls, Kendall System	.0006–.0030	.0046–.0104	.03–.24
" " River System	.0036–.0080	.0096–.0254	.03–.13
Swanton	.0002–.0024	.0074–.0204	.08–.23

In *Orleans County*, the next to the eastward, spring and pond sources are most used; Barton uses the later, while Newport uses some pond water supplied by the Newport Water Company from Derby Pond, a pond one and one-quarter miles long and one-half mile wide, and also some spring water furnished by the Raymond Company. Troy gets its supplies from springs on Jay Mountain. Barton Landing also has a spring water supply.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Newport, Newport Water Company	.0024–.0122	.0062–.0190	.12–.25
" Raymond Company	.0006–.0022	.0034–.0188	.20–.30
North Troy	.0002–.0042	.0060–.0170	.05–.07
South Troy	.0018–.0036	.0060–.0112	.07–.09

In *Essex County*, the northeastern county of the state, Brighton and Island Pond have both spring and pond water; Lunenburg is supplied by two different springs; Canaan uses spring water.

* For complete analyses, see table on page 518.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Brighton	.0006–.0012	.0028–.0082	.07–.24
Canaan	.0006–.0014	.0032–.0056	.08–.12
Lunenburg, Fitzdale, No. 1	.0008–.0022	.0094–.0194	.10–.12
" " No. 2	.0014–.0044	.0136–.0180	.08–.15

Coming to *Chittenden County* on the west, bordering Lake Champlain, we find various kinds of supplies. The city of Burlington uses lake water, the intake being located about two and a half miles from the city, in an opposite direction from the sewer which empties into the lake. As the tables show, the *B. Coli Communis* are found at times, though we think this is due more to the sewage polluted Winooski River entering the lake a few miles north of the city than to our own sewers. Still, if the sewage of Burlington were filtered before entering the lake, it would save the lake from one instance of contamination and in that way put off the time when Burlington will have to filter its water taken from the lake, or else go to the mountains for its supply. At times we are bothered with the taste and odor of the micro-organisms usually found in such surface waters.

Streams furnish water to Milton and Richmond, the latter getting its supply from small streams, and the former from the Lamoille River. The villages of Jericho, Underhill, and Winooski, all use spring water.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Burlington, 1901	.0012–.0034	.0104–.0196	.08–.14
Underhill	.0000–.0024	.0020–.0078	
Winooski	.0006–.0024	.0118–.0278	.14–.23

In *Lamoille County* all the villages use spring water.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Cambridge	.0002–.0048	.0088–.0354	.04–.17
Jeffersonville	.0002–.0034	.0082–.0212	.11–.15
Morrisville, New System	.0010–.0022	.0040–.0100	.04–.13
" Old System	.0012–.0022	.0052–.0076	.04–.13
Stowe	.0004–.0010	.0044–.0048	.18–.21

Washington County has its large towns and cities near one another in the center of the county. The city of Barre has eleven different systems, each supplying fifteen or more families. These use water from springs, brooks, and ponds, the "city water" coming from the latter source. Montpelier is supplied by several springs owned by private parties, and by the city system using water from Berlin Pond. This latter supply we have had occasion to

inspect, and find that the city is endangered by the camps along the shores of the pond and by the unsanitary conditions in several places along the stream on its way from the pond to the Montpelier reservoir. The pond itself, two miles long and one-half mile wide, situated among the hills high above the city, would be an ideal source were the conditions changed; but the city must control the surrounding hills, prohibit camps at the pond, and correct the nuisances along the stream in order to be sure of a safe supply. At present, a single case of typhoid fever among the campers might start a serious epidemic in Montpelier, as about nine tenths of the people use the Berlin Pond water. Northfield has three systems, using waters of springs and brooks. Middlesex has three different spring supplies, as also does Waterbury, getting them from the surrounding hills. Marshfield, also, has a spring supply.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Barre	.0006–.0032	.0104–.0278	.08–.11
Middlesex, Fisher Spring	.0020–.0032	.0062–.0070	.31–.32
„ Miles Spring	.0002–.0038	.0044–.0182	.04–.08
„ Miles-Shepard Sys.	.0002–.0022	.0028–.0094	.05–.13
Waterbury	.0000–.0030	.0026–.0408	.06–.10

The villages in *Caledonia County*, on the New Hampshire line, have a varied supply. Hardwick takes its supply from a pond fed by small mountain brooks, while Lyndon and Lyndonville have four different systems. About three fourths of the latter village use the village system, which takes its water from a brook whose source is in a cedar swamp.. The other systems use spring water running through open brooks to their reservoirs. St. Johnsbury has two systems, — the river system, taking the Passumpsic River water, and the Fairbanks system, with pond water from Stiles Pond, which is one mile in length and three quarters of a mile in width, situated at the base of Waterford Mountain.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Lyndonville Water Company	.0010–.0026	.0114–.0132	.10–.12
St. Johnsbury, River System	.0012–.0034	.0152–.0332	.04–.12
„ Fairbanks Sys.	.0008–.0020		.07–.09

In the county of *Addison*, on the western border of the state, we have the villages of Bristol and Middlebury and the city of Vergennes with public supplies. The first mentioned has spring water from several systems, while Middlebury and Vergennes use

EXAMINATIONS OF WATER FROM VARIOUS WATER SUPPLIES IN VERMONT.

[Parts per 100 000.]

Locality.	Appearance.			Odor.	Residue on Evaporation.			Ammonia.		Chlorine.	Nitrates.	Nitrites.	Hardness.	Bacteria per C. C.	Bacillus Coli Communis.
	Turbidity.	Sediment.	Color.		Total.	Loss on Ignition.	Fixed.	Free.	Albuminoid.						
Franklin County.															
Enosburg Falls (Kendall System)	None.	None to sl.	0.0	None to faint.	10.84	1.36	9.48	.0018	.0062	.13	.0580	.0000	7.1	100– 2 400	At times.
(River System)	None to dist.	None to h'vy.	0.2	V faint to dist.	5.85	1.35	4.50	.0035	.0138	.10	.0230	.0000	3.8	400–10 000	At times.
Richford	None to sl.	None to sl.	0.2	Faint to dist.	3.90	1.44	2.46	.0022	.0136	.09	.0600	.0001	2.2	300– 2 400	None.
Swanton (Intake)	None to dist.	Sl. to cons.	0.4	V. faint to dist.	5.40	1.32	4.08	.0014	.0124	.10	.0300	.0000	3.7	250– 5 400	Us'ly pr.
Orleans County.															
Barton (Barton W. W.)	Distinct.	Cons.	0.4	Faint to dist.	5.10	1.72	3.38	.0046	.0184	.08	.0110	.0000	2.5	Av.– 4 000	At times.
Newport (Newport W. Co.)	V. sl. to dist.	V. sl. to cons.	0.05	None to dist.	16.72	2.06	14.66	.0050	.0124	.18	.1140	.0002	14.0	300– 8 400	At times.
(Raymond Co.)	None to sl.	V. sl. to h'vy.	0.2	None to faint.	14.15	2.65	11.40	.0017	.0090	.25	.2700	.0000	10.1	1 000– 7 200	None.
North Troy	None to dist.	None to sl.	0.1	None to faint.	3.36	1.04	2.32	.0014	.0104	.06	.0220	.0000	2.1	214– 3 800	None.
South Troy	Sl. to dist.	Sl. to cons.	0.1	V. ft. to dist.	4.32	2.09	3.23	.0028	.0076	.08	.0300	.0000	2.8	300–11 400	None.
Essex County.															
Brighton and Island Pond	None to v. sl.	None to v. sl.	0.3	None to faint.	4.40	1.35	3.05	.0034	.0136	.15	.0060	.0000	2.4	500–12 000	None.
Canaan (Public System)	None to sl.	None to sl.	0.0	None to faint.	7.08	1.34	5.74	.0016	.0055	.11	.1070	.0000	4.7	100– 400	None.
Lunenburg (King Spring)	Very slight.	Slight.	0.0	None to v. ft.	6.52	1.52	5.00	.0012	.0082	.19	.1900	.0000	2.7	Av.– 100	None.
(Day Spring)	Very slight.	V. sl to sl.	0.0	None to v. ft.	5.76	0.84	4.92	.0030	.0116	.15	.0900	.0000	2.7	Av.– 100	None.
(Fitzdale No. 1)	Sl. to dist.	V. sl. to sl.	0.1	None to dist.	3.80	1.30	2.50	.0015	.0144	.11	.1100	.0003	1.8	100– 2 400	None.
(Fitzdale No. 2)	Sl. to dist.	Sl. to cons.	0.3	one to dist.	4.76	1.86	2.90	.0038	.0158	.12	.0400	.0000	2.8	2 300–10 000	None.
Chittenden County.															
Burlington (Tap in Lab. 1899)	None to sl.	None to v. sl.	0.2	None to faint.	6.67	2.05	4.62	.0026	.0137	.14	–	–	3.6	35– 216	At times.
(Tap in Lab. 1900)	None to sl.	None to v. sl.	0.2	None to faint.	7.20	2.16	5.04	.0040	.0140	.22	–	–	3.6	250– 336	At times.
(Tap in Lab. 1901)	None to dist.	None to v. sl.	0.2	None to dist.	6.85	1.63	5.22	.0017	.0132	.10	.0150	.0000	4.5	100– 700	At times.
Richmond	None.	None to v. sl.	0.0	None to faint.	10.32	2.00	8.32	.0016	.0068	.16	.1800	.0000	7.4	80– 100	None.
Underhill	None to v. sl.	V. sl. to sl.	0.0	V. faint to ft.	5.92	1.04	4.88	.0018	.0070	.07	.0820	.0001	4.0	100– 1 400	None.
Winooski (W. W.)	None to dist.	None – cons.	0.4	None to dist.	6.05	1.45	4.60	.0014	.0160	.16	.0230	.0001	3.7	140– 5 800	None.
Lamoille County.															
Cambridge	None to v. sl.	V. sl. to sl.	0.0	None to dist.	4.20	1.10	3.10	.0010	.0112	.11	.0110	.0000	2.6	100– 3 400	None.
(Jeffersonville System)	None to sl.	V. sl. to cons.	0.1	None to faint.	6.10	1.58	4.52	.0016	.0146		.1100	.0000	3.9	100– 3 600	At times.
Hyde Park (Village System).															
(Spring No. 1)	None.	None.	0.0	None to v. ft.	6.90	1.30	5.60	.0012	.0028	.12	.1800	.0000	4.0	100– 3 600	None.
(Spring No. 2)	None.	Very slight.	0.0	None to v. ft.	5.90	0.95	4.95	.0004	.0022	.12	.2000	.0000	3.7	100– 6 600	None.
(Spring No. 3)	None.	Very slight.	0.0	None to v. ft.	23.70	6.20	17.50	.0002	.0016	2.40	.5000	.0000	10.8	1 000–c'tless	None.
Morrisville (New System)	None to v. sl.	None to v. sl.	0.0	None to faint.	6.19	1.01	5.18	.0014	.0062	.11	.0600	.0000	5.1	110– 2 400	At times.
(Old System)	None to dist.	V. sl. to h'vy.	0.0	None to dist.	6.75	1.15	5.60	.0017	.0064	.11	.0560	.0000	5.3	80– 2 400	At times.
Stowe (Village System)	None to sl.	V. sl. to sl.	0.0	None to v. ft.	7.20	1.50	5.70	.0005	.0030	.26	.1580	.0000	5.6	50– 850	None.
Washington County.															
Barre (City Water)	Sl. to dist.	Sl. to heavy.	0.3	V. ft. to dist.	14.42	1.60	12.82	.0025	.0218	.10	.0150	.0000	11.7	100– 1 800	At times.
Marshfield	None to dist.	V. sl. to h'vy.	0.0	None to dist.	3.58	0.83	2.75	.0020	.0082	.11	.0990	.0002	2.3	500– 3 600	None.
Middlesex (Fisher Spring)	None to sl.	None to sl.	0.0	None to dist.	4.78	1.66	3.12	.0023	.0065	.32	.1000	.0000	2.1	–	At times.
(Miles Spring)	V. sl. to dist.	V. sl. to cons.	0.0	None to dist.	2.70	0.45	2.25	.0005	.0070	.06	.0240	.0000	1.5	350– 2 600	None.
(Miles-Shepard System)	None to v. sl.	None to sl.	0.0	None to dist.	2.25	0.47	1.78	.0007	.0062	.06	.0360	.0000	1.1	550– 2 000	At times.

Montpelier (Middle Berlin Pond)*	Dist.	Very slight.	0.1	Dist.	10.00	1.30	8.70	.0010	.0158	.10	.0050	.0000	7.6	400	None.
(Intake Reservoir)*	Dist.	Cons.	0.3	Dist.	10.60	1.80	8.80	.0032	.0202	.14	.0090	.0000	7.7	4 000	Present.
(Av. Tap in City)	Dist.	Sl. to cons.	0.3	Dist.	10.26	1.26	9.00	.0041	.0162	.12	.0060	.0000	7.9	2 750– 4 000	At times.
Northfield (R. R. System)	Dist.	Cons. to h'vy.	0.0	V. faint to ft.	9.12	0.92	8.20	.0022	.0116	.09	.0400	.0000	6.9	500– 2 100	Present.
(Dutton System)	V. sl. to sl.	Sl. to cons.	0.0	None to faint.	5.92	1.20	4.72	.0008	.0104	.07	.0380	.0000	2.0	800– 1 000	None.
(Emerson System)	Sl. to dist.	Sl. to cons.	0 1	V. faint to ft.	12.80	1.40	11 40	.0012	.0078	.07	.0820	.0000	7.4	800– 1 000	None.
Waterbury (Village System)	None to sl.	None to v. sl.	0.0	None.	4.06	0.76	3.30	.0011	.0084	.07	.0400	.0000	2 4	200– 2 000	None.
Caledonia County.															
Barnet (Public System)	None to v. sl.	V. sl. to sl.	0 0	None.	6.30	0.80	5.50	.0004	.0028	.07	.0300	.0000	5.4	Av.– 200	None.
Hardwick	Very slight.	V. sl. to cons.	0.2	None to dist.	8.88	1.16	7.72	.0006	.0012	.07	.05 0	.0000	6.0	400– 3 600	None.
Lyndon (Public System)	None.	None to sl.	0.0	None to faint.	15.60	2.00	13 60	.0014	.0046	.09	.0190	.0000	13.0	200– 1 100	At times.
Lyndonville (L. Water Co.)	V. sl. to dist.	V. sl. to cons.	0.5	Faint to dist.	14.00	2 20	11.80	.0018	.0124	.11	.0110	.0000	9.4	200– 9 600	At times.
(Railroad System)	None to v. sl.	None to v. sl.	0.0	None to faint.	15.25	1.40	13 85	.0000	.0030	.08	.0190	.0000	12.2	485– 900	None.
(L. Village System)	None to dist.	None to cons.	0.7	None to dist.	11.40	2.80	8.60	.0012	.0174	.08	.0100	.0000	7.1	500– 3 500	At times.
St. Johnsbury (River System)	Sl. to decid.	Heavy.	0.4	Faint to dist.	8.70	1.90	6.80	.0024	.0224	.10	.0240	.0000	6.3	700– 1 800	At times.
(Fairbanks System)	V. sl. to sl.	Sl. to cons.	0.4	Faint to decid.	5.08	1.68	3.40	.0014	.0194	.08	.0210	.0000	2.6	300– 1 260	None.
Addison County.															
Bristol (East St. Aq. Co.)	None.	None.	0.0	None to faint.	17.25	2.60	14.65	.0002	.0018	.12	.0090	.0000	14.6	All about same, 100–1 700	At times.
(Rock Sp. Water Co.) (No. Mt. Sp.)	None.	None to v. sl.	0.0	None to v. ft.	3.25	0.25	3.00	.0022	.0038	.11	.0100	.0000	1.4		None.
(River Sp.)	None.	None to v. sl.	0.0	None to v. ft.	8.80	1.30	7.50	.0030	.0090	.09	.0420	.0000	7.9		None.
(Bristol Aq. Co.) (Middle Sp.)	None.	None to v. sl.	0.0	None.	4.25	0.25	4.00	.0024	.0080	.11	.0060	.0000	3 1		At times.
(North Sp.)	None.	None.	0.0	None.	4.65	0.30	4.35	.0060	.0020	.09	.0060	.0000	3.5		At times.
(South Sp.)	None.	None.	0.0	None.	4 35	0.35	4.00	.0024	.0076	.10	.0060	.0000	3.5		At times.
Middlebury (Creek System)	V. sl. to dist.	V. sl. to cons.	0.3	Faint to dist.	8.84	2.88	5.96	.0044	.0136	.18	–	–	4.0	4 200–10 000	Present.
Vergennes. (City Water) [1]	None.	Cons. to h'vy.	0.6	Dist. to decid.	9.84	2.28	7.56	.0152	.0444	.09	.0300	.0001	5.4	4 000 –	Present.
(City Water) [2]	Slight.	Very slight.	0.4	Faint to dist.	9.50	1.90	7.60	.0014	.0156	.12	.0110	.0000	7.4	c'ntless.	Present.
Orange County.															
Bradford	None to sl.	V. sl. to sl.	0.1	V. ft. to dist.	6 83	1 13	5.70	.0015	.0112	.09	.0080	.0000	4.9	100– 3 200	None.
Randolph	None to sl.	None to sl.	0.0	None to dist.	10.60	1.38	9.22	.0009	.0067	.11	.1030	.0000	8 5	100– 1 000	None.
Rutland County.															
Brandon (Fern Lake)	None to dist.	None to cons.	0.0	V. ft. to dist.	11.00	3.13	7.87	.0112	.0194	.10	.0030	.0000	7.3	100– 2 000	At times.
Pittsford	None to dist.	V. sl. to cons.	0.0	None to v. ft.	9.85	1.73	8.12	.0016	.0055	.09	.0450	.0000	7.9	100– 490	None.
Poultney (Lake System)	Distinct.	Cons.	0.4	Distinct.	5.18	0.90	4.28	.0014	.0266	.08	.0050	.0000	3.9	200– 300	At times.
Proctor	V. sl. to dist.	V. sl. to sl.	0.1	V. ft. to dist.	14.86	3.49	11 37	.0026	.0124	.10	.0110	.0000	13.6	80– 9 700	At times.
Center Rutland	None to v. sl.	V. sl. to cons.	0.0	None to v. ft.	6.32	0.75	5 57	.0012	.0060	.07	.0020	.0000	4.8	100– 1 000	None.
City of Rutland	V. sl. to sl.	V. sl. to cons.	0.3	V. ft. to dist.	5.76	1.56	4.20	.0015	.0100	.10	.0170	.0000	3.8	150– 6 600	Present.
Windsor County.															
Chester	V. sl. to sl.	Very slight.	0 1	V. faint to ft.	4.85	0.98	3.87	.0019	.0132	.10	.0150	.0002	2.2	300– 600	None.
Hartford (Water Co.)	None to v. sl.	None to v. sl.	0.0	Faint.	7 21	0.92	6.32	.0018	.0106	.12	.0080	.0000	3.6	Very high.	None.
Norwich (Norwich W. Co.)	None to v. sl.	None to cons.	0.0	None to faint.	7.37	0 69	6.68	.0010	.0052	.10	.0130	.0000	5.5	300– 2 400	At times.
(Armstrong Supply)	None to v. sl.	V. sl. to sl.	0.0	None to faint.	12.26	1.44	10.82	.0014	.0078	.15	.0750	.0000	7.9	100– 1 100	None.
Rochester (Public Sup. Sp. No. 1)	None to v. sl.	None to v. sl.	0.0	None.	4 30	0.90	3.40	.0030	.0060	.11	.1100	.0000	3.0	Av.– 300	None.
Windsor (Village System)	None.	None.	0.0	V. faint to ft.	11.84	0.96	10.88	.0014	.0014	.10	.0190	.0000	8.9	Av.– 900	None.
Bennington County.															
Arlington	None.	None.	0.0	None.	11.20	1.10	10.10	.0004	.0038	.07	.0200	.0000	8.1	200– 416	None.
Bennington (City Water)	None.	None.	0.2	None to faint.	3.02	0.96	2.06	.0032	.0096	.10	.0580	.0000	1.5	50– 500	None.
Manchester (Village System)	None.	Very slight.	0.0	Faint to dist.	2.18	0.38	1.80	.0014	.0046	.07	.0390	.0000	1.6	300– 900	None.
(Center System)	None to v. sl.	None to v. sl.	0.0	Faint to dist.	4.10	0.54	3.56	0008	.0044	.06	.0370	.0001	3.1	110– 960	None.
Windham County.															
Bellows Falls (Minard Pond Water)	Distinct.	Sl. to heavy.	0.2	Faint to dist.	3.20	1.11	2.09	.0022	.0164	.11	.0030	.0000	1.3	960– 7 600	Present.
Brattleboro (West River)	Slight.	V. sl. to sl.	0.3	V. faint to ft.	2.76	1.16	1.60	.0011	.0112	.09	.0070	.0000	0.8	500– 800	None.
(Western Aqueduct)	None to v. sl.	None to v. sl.	0.0	None to faint.	11.18	2.22	8.96	.0009	.0034	.29	.2280	.0000	7.8	100– 4 800	None.

*Taken on same day.

[1] Average Spring Analysis.

[2] Average Summer Analysis.

the water from Otter Creek, a small, highly-contaminated stream, carrying the sewage of Rutland and numerous towns before it reaches Middlebury. However, Middlebury is now putting in a new system of spring water from sources in the Green Mountains.

The towns of Randolph and Bradford in *Orange County* use spring and brook water, respectively.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Bradford	.0002–.0034	.0060–.0168	.06–.12
Randolph	.0002–.0014	.0032–.0078	.08–.14

In *Rutland County*, Brandon and Poultney use lake waters from Fern Lake and Lake St. Katherine, the latter being 5 by 1.5 miles in extent. Proctor uses spring water, and the city of Rutland uses water from mountain brooks which have their sources in the Green Mountains. This is another supply whose streams should be controlled by the city and inspected at frequent intervals. Center Rutland gets its supply from springs in the neighboring hills.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Brandon	.0030–.0220	.0186–.0218	.07–.09
Pittsford	.0014–.0020	.0032–.0082	.08–.12
Proctor	.0006–.0048	.0116–.0146	.08–.12
Rutland (City)	.0008–.0024	.0064–.0142	.07–.11

Windsor County, on the eastern border, is made up of small towns all using spring water.

	Free Ammonia.	*Albuminoid Ammonia*	*Chlorine.*
Chester	.0008–.0032	.0092–.0190	.08–.11
Hartford	.0010–.0072	.0078–.0152	.10–.20
Norwich, Village System	.0000–.0026	.0044–.0062	.10–.13
„ Armstrong System	.0010–.0018	.0072–.0084	.14–.16

Bennington County, on the southern border, has its towns all using spring water, Manchester getting its supply from springs on Equinox Mountain.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Bennington	.0018–.0048	.0078–.0108	.04–.16
Manchester, Village System	.0006–.0028	.0044–.0188	.03–.13
„ Center System	.0004–.0016	.0006–.0078	.03–.09

The two villages in *Windham County*, the last on the southern border, having public supplies are, Bellows Falls, taking its supply from Minard Pond, and Brattleboro, using river water from West River and spring water in its so-called Western Aqueduct Supply.

	Free Ammonia.	*Albuminoid Ammonia.*	*Chlorine.*
Bellows Falls	.0016–.0036	.0152–.0204	.10–.15
Brattleboro, Western Aqueduct	.0000–.0024	.0014–.0044	.25–.34
" West River	.0006–.0016	.0090–.0136	.08–.11

As will be noticed in the tables, the chlorine in most cases is below 0.10 parts in 100 000; and although we are not yet prepared to give the normal chlorine for Vermont, still it seems from our data at present as if it varied but little in different parts of the state, and is very similar to that in western Massachusetts.

While these results are brief and incomplete, still they may give some better idea of some of the water supplies of Vermont, and thus increase our knowledge of the waters of New England.

FALL OF THE FAIRHAVEN WATER TOWER.

AN INFORMAL TALK BY R. C. P. COGGESHALL, SUPERINTENDENT NEW BEDFORD WATER WORKS.

[*At the Meeting of November 13, 1901.*]

The city of New Bedford is located upon the west side of the Acushnet River. The town of Fairhaven is upon the east side directly opposite. One of the principal features of the water works of this town was the water standpipe, which was a landmark familiar to every one thereabouts and visible for many a mile in every direction. This was located just north of the highway leading east from the center of the town and about three-quarters of a mile distant from that center.

This tower attracted considerable attention at the time it was erected in 1893, and has been the model of several similar structures. It was fully described in a paper, illustrated by drawings, presented to this Association by Mr. Joseph K. Nye, superintendent of the Fairhaven Water Works, in 1894.*

This tower completely collapsed on Saturday afternoon last, November 9, at about four o'clock. I have obtained several photographs of the wreckage as it now lies, which I thought might be of interest to you. I also have a view of the tower as it appeared before the disaster. These photographs will illustrate the condition of things better than any verbal description I can give.

This first picture, Plate I, is a view showing the standpipe as it had stood since its erection, seven or eight years ago. Plate II, Fig. 1, is a view taken from the top of the draw of the new bridge connecting Fairhaven with New Bedford, and in the distance you will see how distinctly the standpipe cuts the horizon.

The following data may be of interest: —

Total height of tower	200 feet.
Length of supporting legs	100 feet.
Height of tank	50 feet.

*JOURNAL, Vol. viii, p. 175. It should be noted, however, that the standpipe as built differed in several important details from the drawings published.

FAIRHAVEN STANDPIPE.

FIG. 1. — VIEW FROM NEW BEDFORD-FAIRHAVEN BRIDGE. STANDPIPE IN THE DISTANCE.

FIG. 2. — WRECK OF FAIRHAVEN STANDPIPE.

WRECK OF FAIRHAVEN STANDPIPE.

PLATE III.

FIG. 1. — BOTTOM OF WRECKED FAIRHAVEN STANDPIPE.

FIG. 2. — WRECK OF FAIRHAVEN STANDPIPE.

FIG. 1. — WRECK OF FAIRHAVEN STANDPIPE.

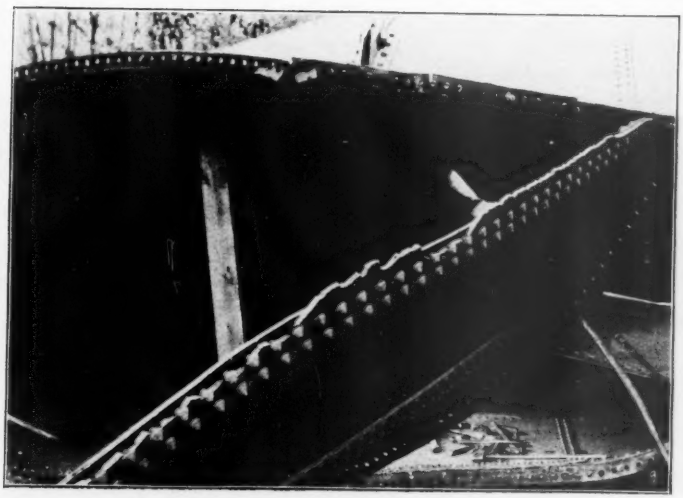

FIG. 2. — WRECK OF FAIRHAVEN STANDPIPE.

Diameter of tank	35 feet.
Height of roof	50 feet.
Capacity when full	383 000 gallons.

There were apparently no unusual conditions at the time of the disaster. There was little or no wind, and the tank lacked considerable of being full. There has been more or less leakage from the bottom joints in the past; but I understood that this had been remedied. The general opinion seems to be that the conical bottom opened up in one of its seams, allowing the heavy mass of water to drop upon the foundation, knocking out the foundation of the supporting legs. This caused the whole structure to shut up like a knife. The several photographs show how the stone wall which marked the line of the company's lot was distributed around the pasture in the foreground. This wall was completely swept away. A horizontal rotary motion was imparted to the tank as it fell, as is shown by the twist and direction in the bending of the supports.

Two boys were riding by on a tandem bicycle when the break occurred. One jumped from the wheel and was caught by the torrent of water and carried over the stone wall into the field on the south side of the road. His companion stuck to the wheel until it struck the wall, when he, too, was landed into the open field. A man driving a heavy cart was lifted from his seat by the flood and landed at a considerable distance. While none was killed, all three received injuries of a more or less serious nature.

Plate III is a view of the wreck from a position in the field east of the foundation. The roadway is at the left side. A stone wall which marked the line of the water company's lot is seen distributed about the pasture in the foreground. Among this assortment of rocks is a portion of the rubble masonry foundation. At the left of the center of the picture is seen one of the two-ton blocks that was kicked by a leg as it was ripped from its anchorage. The fallen legs, some broken, others twisted and bent, lie in a pile across the center of the picture. Just behind is the side of the tank, the bottom being toward the roadway at the left, and the top is seen over the heads of a group of four men in the middle ground of the picture, with a part of the gallery visible. The tank as it fell revolved around on its own axis more than half way, and while one section of the conical bottom lies in the street, the other part is folded under the heap. The steep conical roof, of one-eighth-inch galvanized plate, is seen in the upper right quarter of the photograph, the tip toward the north.

Such a disaster always brings forth a variety of opinions as to the cause. This is no exception. A number of theories have been advanced. I think, however, we shall wait with interest for the reports of the experts who now have the matter under investigation.

AN INFORMAL ADDRESS.

BY JOHN O. HALL, MAYOR, QUINCY, MASS.

[*Delivered November 13, 1901.*]

Mr. President and Gentlemen of the New England Water Works Association, — It was with a great deal of diffidence that I consented, at the request of your President, to say a word this afternoon, because I always feel very insignificant when I meet with the members of the New England Water Works Association. It has been a source of regret to me that my line in life did not lead me to deal with actual, material things; that I was not permitted to be a mechanic in the true sense; that I was not permitted to study those sciences which deal with the practical and material matters of life. It has been my fortune at one or two of your meetings to listen to essays which were illustrated by diagrams, — cross sections of engines and pumps and matters of that sort, — and my absolute ignorance of things of that kind led me to feel my insignificance more than ever. Taking up a copy of the JOURNAL, a short time since, I found in it an article illustrated with a diagram — a cross section, I think, of a pump — and I resolved to make myself master of the article, with the help of the diagram and the dimensions given, but after a few minutes' study I abandoned the attempt in despair. It was "hieroglyphics" to the last degree to me. Not only was I not able to comprehend it, but I was utterly unable to get the first inkling of what it meant. And then my insignificance, as I remembered my experience with the members of the New England Water Works Association, impressed me more forcibly than ever.

I have a great respect for the members of the New England Water Works Association. I have a great respect for the men who have made the tap in the sink possible, for I have a very distinct recollection of wrestling in my younger days with the pump. When you go out into the back shed at night, with the thermometer down below zero and the frost sending its fingers under the back shed door, and pump and pump and pump and pump and pump and pump, in order that you may have water for the

preparation of the morning breakfast, and when you are all ready to see the water come from the spout, you hear a sinking sound 'way down somewhere under the ground and a faint last gurgle, and realize that the bottom box is out of order and the water is gone for good, I assure you that you can realize that the tap in the sink is a luxury indescribable. I have a great respect for, and my emotions are deeply stirred when I read or when I think of, the "old oaken bucket that hung in the well." But at four o'clock on a winter morning, with the ground cased in ice, if you take the bucket and start for that well, and you find yourself sliding to that well on the fattest part of your body, with your head and your heels in the air and the bucket gone from you, you know not where, then your respect for the men who made the tap in the sink possible will increase an hundredfold.

I have been greatly pleased in listening to the papers this afternoon, because they show the paternal care of governments exercised for the benefit of the citizens. I listened yesterday to papers in reference to the construction of highways, and the remark was made that all sands were alike; and yet before the essay was completed I realized that there were varieties of sand, and those varieties were differently useful in different cases. At one time people supposed that water was water, but we have come to realize that there are great differences in water and to consider it scientifically, so that by protecting the purity of the water we are doing much for the health and comfort of our communities. This has been largely the result of the work of such associations as yours, and of the work of men who have made a scientific study of these things, and advanced step by step from the inconvenience of our original civilization up to the scientific basis of our civilization to-day. And when I think that it is possible for a community to contribute men and money and materials so that a whole state can be classified as to its water-producing facilities and to the qualities of the water produced, so that all affairs of the communities of the state can be so administered that they shall not contribute to the injury of those water facilities, and in the process of civilization everything that is detrimental to the quality of the water and, therefore, to the citizens of the state who use it, can be removed—and this not at the expense of the individual, but, by the assistance of science, to the profit of the individual, so that the waters are rendered purer and at the same time he secures additional profit to his manufacture; so that the board of engineers

furnishing a community with pure water are the servants of the community in advancing civilization, and also the servants of the individuals of the community by increasing their sources of wealth, — I realize that you gentlemen are indeed adding to the general welfare, to the public health, and to the building up of a better community.

There are two sides to this question of pure water: first, as to the quality; second, as to the distribution. You want to distribute water of a pure quality, but in that work you encounter numerous difficulties, some of them seemingly insurmountable. The nature of your country, the location of the community that you wish to supply, the extent of your supply, and the increased demand on the supply that you have available, are problems which call upon you for the exercise of your highest powers. One difficulty which you encounter, aside from the physical difficulties to be overcome, is to secure the means wherewith to accomplish what you desire to do. And in that direction we, who are not skilled engineers, can bear our part and can assist and serve in the method and in the manner and in the extent of the appropriations which can be made and must be made by the governmental department of any community. One obstacle is often the lack of harmony between the engineer, the practical superintendent, and the legislative board which controls the appropriations. You consult with your executive, and in your wisdom and experience and knowledge forecast the entire situation; but the legislative board refuses to appropriate the money for that which your wisdom teaches you should be done, while it may furnish you with an appropriation for the accomplishment of that which you do not desire and which is not proper at that stage of the development of the enterprise. Therein lies the duty and the opportunity of those who hold such positions as I do; and I assure you that the benefits arising from an intimate acquaintance with an association of this sort will enable one the better to accomplish the full and perfect and complete supply of the citizens with water of pure quality and generous quantity. The paternal nature of our governments, I think, is shown in the readiness and the facility with which they so often contribute to your wants. It is not so much a question of penuriousness that leads governments to misappropriate or not to appropriate a sufficient sum, as it is a lack of knowledge, a lack of confidence, a lack of community of coöperation in performing the labor which rests upon us; and, so far as I am concerned, I am glad to

see that there is an increased desire, determination, and purpose to coöporate in the promotion of the public welfare and in the development of those things which tend to the prosperity and health of our communities. We are making great progress; we have calls without number, and we are appalled sometimes at the stupendous work which is before us, and discouraged at our lack of progress; but when we compare the facilities which we have to-day and measure the great results which we are accomplishing, with the condition of affairs a generation or two ago, we are infinitely encouraged. And I believe the position which we hold to-day will enable us in another generation to produce results which will make the enjoyment of living upon this earth something beyond the contemplation or comprehension of the men of to-day.

PROCEEDINGS.

November Meeting.

YOUNG'S HOTEL, BOSTON, MASS.
November 13, 1901.

President Crandall in the chair.
The attendance was as follows: —

MEMBERS.

Charles H. Baldwin, Lewis M. Bancroft, M. N. Baker, Joseph E. Beals, James F. Bigelow, Dexter Brackett, Edwin C. Brooks, George A. P. Bucknam, G. L. Chapin, John C. Chase, Harry W. Clark, Freeman C. Coffin, R. C. P. Coggeshall, F. H. Crandall, M. F. Collins, Arthur W. Dean, Jasper A. Fitch, Frank L. Fuller, Stephen DeM. Gage, J. C. Gilbert, Albert S. Glover, E. H. Gowing, Frank E. Hall, John O. Hall, J. C. Hammond, Jr., L. M. Hastings, Horace G. Holden, J. W. Kay, Willard Kent, Patrick Kieran, L. P. Kinnicutt, C. F. Knowlton, A. E. Martin, Frank E. Merrill, Leonard Metcalf, C. P. Moat, J. W. Moran, Frank L. Northrop, H. N. Parker, J. B. Putnam, W. H. Richards, W. W. Robertson, Charles W. Sherman, George A. Stacy, Charles N. Taylor, Robert L. Thomas, H. L. Thomas, W. H. Thomas, D. N. Tower, G. W. Travis, W. H. Vaughn, Charles K. Walker, C.-E. A. Winslow, George E. Winslow.

ASSOCIATES.

Harold L. Bond & Co., by Harold L. Bond; Builders' Iron Foundry, by F. N. Connet; Chapman Valve Mfg. Co., by Edward F. Hughes; Coffin Valve Co., by H. L. Weston; International Steam Pump Co., by George J. Foran; Hersey Mfg. Co., by Albert S. Glover and James A. Tilden; Henry F. Jenks; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Ludlow Valve Mfg. Co., by H. F. Gould; National Meter Co., by Charles H. Baldwin and J. G. Lufkin; Neptune Meter Co., by H. H. Kinsey; Perrin, Seamans & Co., by J. C. Campbell; Rensselaer Mfg. Co., by Fred S. Bates; A. P. Smith Mfg. Co., by W. H. Van Winkle; Union Water Meter Co., by J. P. K. Otis and Frank L. Northrop; United States Cast Iron Pipe and Foundry Co., by L. R. Lemoine.

GUESTS.

John H. Cook, East Jersey Water Co., Paterson, N. J.; H. V. Macksey, Boston Water Works, Boston, Mass.; F. B. Skinner, Rockville, Conn.;

W. J. Welch, Boston Water Works, Boston, Mass.; Charles A. Donovan, Water Commissioner, Lawrence, Mass.; Frederick A. Beals, Water Registrar, Everett, Mass., and E. P. Walters, Metropolitan Water Works, Boston, Mass.

Mr. R. C. P. Coggeshall, of New Bedford, was called upon by the President to say something in regard to the collapse of the Fairhaven water tower, and he responded by a brief description of the tower and its wreck, illustrating his remarks by numerous photographs.

The first paper of the afternoon was by H. W. Clark, chemist, Massachusetts State Board of Health, on "Pollution of Streams by Manufactural Wastes — Methods of Prevention."

Prof. L. P. Kinnicutt, of Worcester, also spoke upon the same subject.

Mr. Charles P. Moat, chemist, Vermont State Laboratory of Hygiene, Burlington, Vt., then read a paper on "Water Supplies of the State of Vermont."

Mayor John O. Hall, of Quincy, then, by invitation of the President addressed the Association.

The following new members were elected: —

Herman W. Spooner, Gloucester, Mass., Engineer of Construction of Water Works.

George F. West, Portland, Me., Manager of Water Works.

Walter M. Scott, Charlottetown, P. E. I., Engineer.

Edward W. Bemis, Cleveland, Ohio, Superintendent Cleveland Water Works.

Edwin A. Fisher, Rochester, N. Y., City Engineer.

Adjourned.

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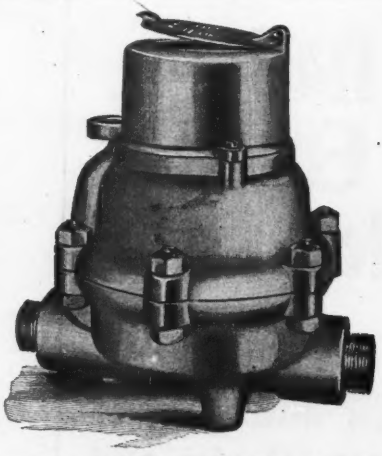

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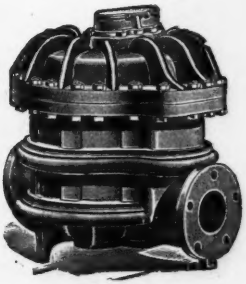

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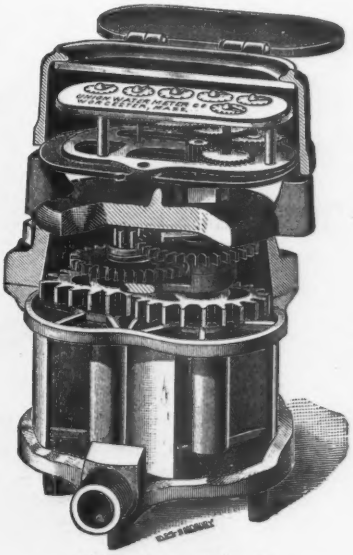

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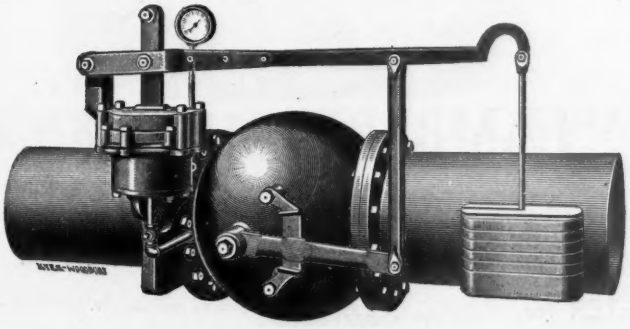

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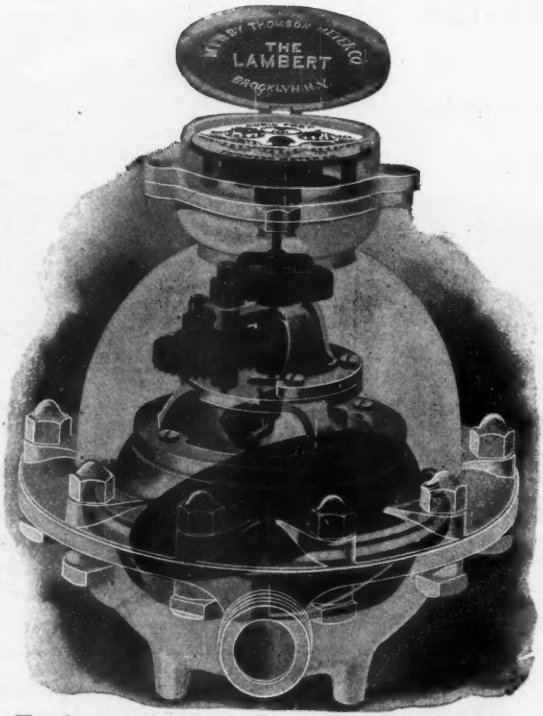

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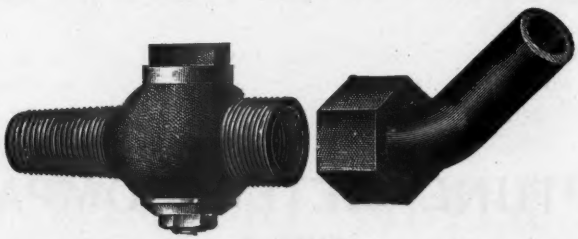

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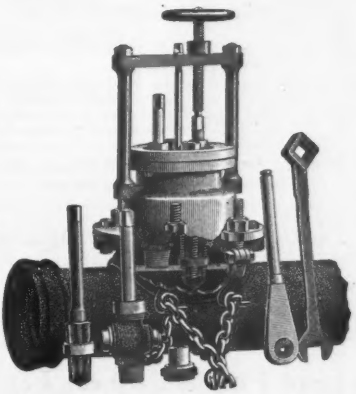

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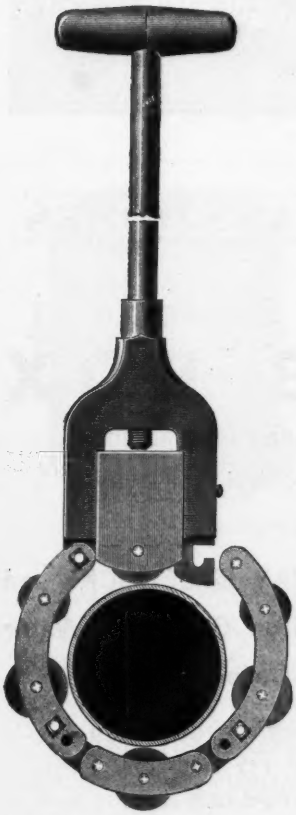

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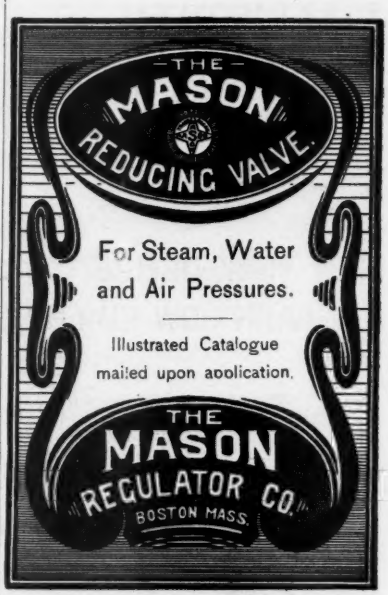

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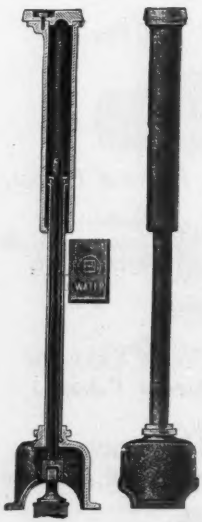

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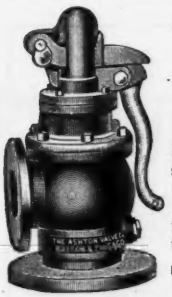

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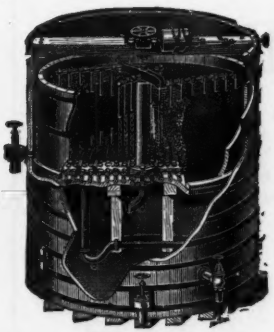

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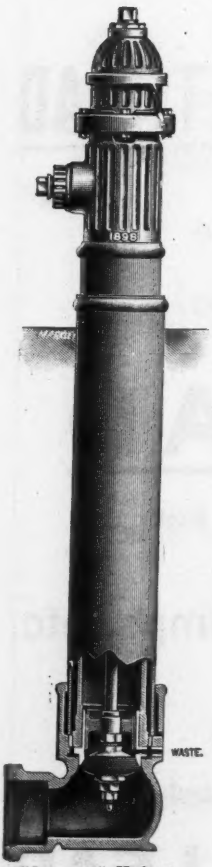

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Special Castings for Water and Gas.
Also Flange Pipe, Lamp Posts, Street Castings,
Manhole Heads and Covers, etc.

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"No special made to-day compares with the Globe Special as to convenience in handling."

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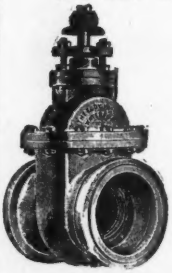
Eddy Fire Hydrants combine all the good features of other makes, and many very desirable ones besides, making them ***the Standard of Excellence.***



WE ALSO MANUFACTURE CHECK, FOOT AND AIR VALVES, SLUICE GATES, INDICATOR POSTS, WATER CRANES, FLUSH HYDRANTS, Etc., Etc.

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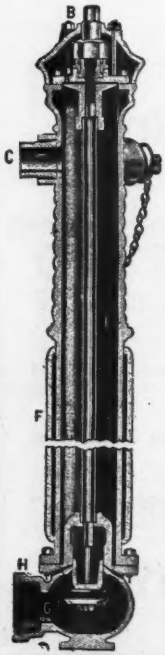

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THE VALVES
AND HYDRANTS

Manufactured by the

KENNEDY VALVE MFG. CO.

ARE

SIMPLE
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Prices and particulars on application to their office at

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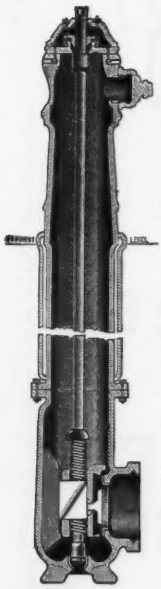

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... MANUFACTURERS OF ...

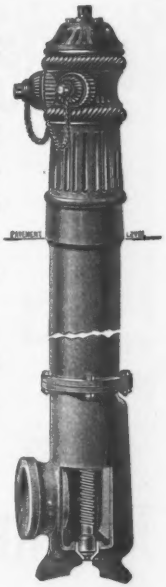
VALVES AND FIRE HYDRANTS

This hydrant is anti-freezing, because when the drainage is good no water is left in it to freeze.
The drip is directly in the bottom of the hydrant and drains perfectly. It is protected by its valve, which never leaves its socket and cannot be clogged.

DOUBLE AND SINGLE GATE VALVES,
ALSO CHECK VALVES,
FOOT VALVES.

FIRE HYDRANTS.

YARD, WASH, AND FLUSH HYDRANTS.



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OFFICE AND WORKS: FOOT OF ADAMS STREET, TROY, N. Y.

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Fire Hydrants

Valve opens down
Valve has rubber face
Valve cannot chafe
No water hammer
Buckling rods avoided
Valve removed without digging
Least loss by friction
Best waste device

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For Water, Gas, Steam or Oil.

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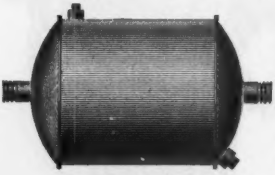
WE have had over twenty-four years' experience in supplying cities, towns, and large corporations by the Artesian and Driven Well system. Also driven many thousand wells for domestic purposes.

Sand and Vacuum Chambers.



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We have patented and manufacture sand chambers. Smaller sizes fitted for 1½-in. to 6-in. pipes, made of heavy hammered copper, guaranteed not to leak or collapse. Larger chambers for water works where from 500,000 to 6,000,000 gallons of water are pumped, made of wrought-iron, fitted with 8-in. to 20-in. pipe. All chambers are warranted to stop sand, or money refunded, if we know the quantity of water to be pumped and the quality of sand. Call on or address,

B. F. SMITH & BRO., 38 Oliver Street, Boston.

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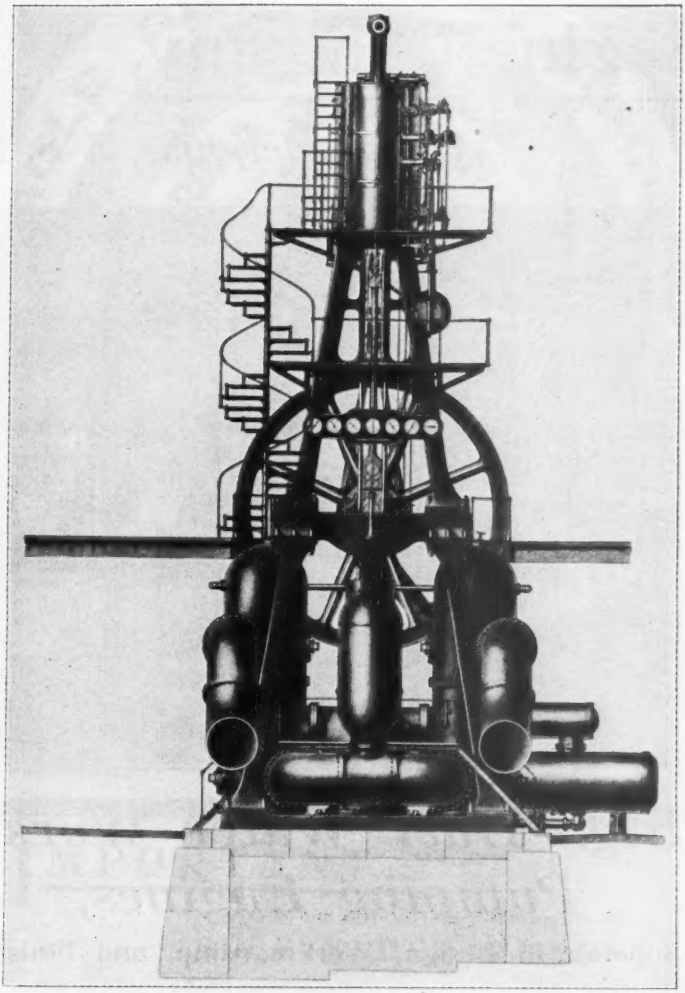

Holly High Duty Pumping Engine, No. 9. Spot Pond Pumping Station, Metropolitan Water Works, Boston, Mass. Daily Capacity, 20,000,000 gallons. Duty (official test), 177,961,000 foot-pounds per 100 pounds dry coal.

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J. S D M.

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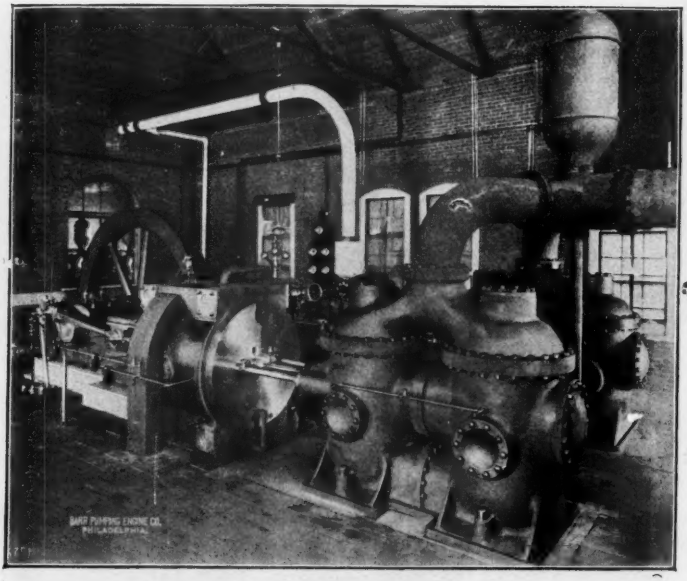

High Duty Water Works Pumping Engines,

Superior in Design, Workmanship, and Finish.

PUMPS OF ALL DESCRIPTIONS.

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Telephone 2577-2.

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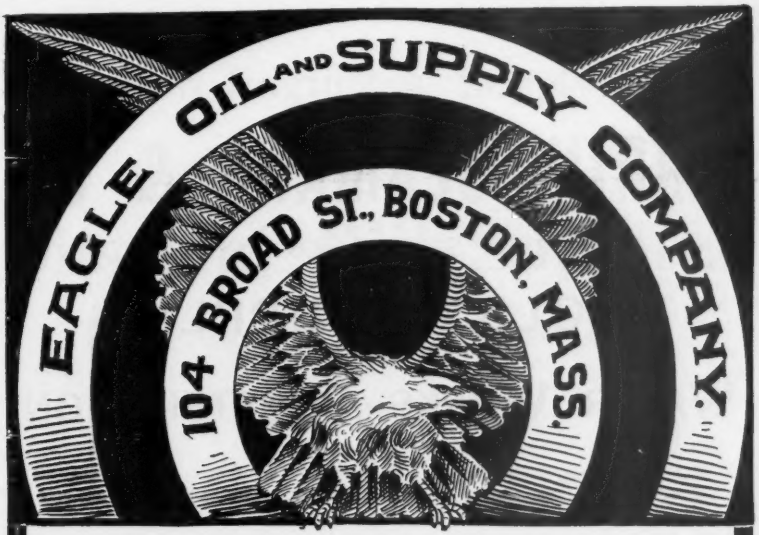

Don't think so much what OIL is going to cost; think more about what it is going to do.

SOLE MANUFACTURERS OF

EAGLEINE HIGH PRESSURE CYLINDER OIL

We manufacture an Oil especially adapted for pumping machinery, and in all cases it has given excellent results. Many members of this Association have been customers of ours for years, and speak in the highest terms of our **Eagleine Cylinder Oil**, and the results obtained by its use have been very satisfactory. We solicit a trial order, and will send a sample barrel on thirty or sixty days' trial.

NEW ENGLAND AGENTS FOR

SOLARINE METAL POLISH

For Brass, Steel, and Nickel-plate

FREE SAMPLE

IMPORTANT...

In connection with our Oil and Grease Departments we have a

SUPPLY DEPARTMENT

This we wish to call your special attention to for the following reasons: First, we carry a stock of supplies used in Pumping Stations second to none in our city; Second, we guarantee to deliver exactly what we represent, and will stand all expenses if we do not; Third, we can deliver goods promptly, and our prices are low for what we deliver; Fourth, by having such an extensive supply department to order from it enables you to keep your Oil, Grease, and Supply account under one head. REMEMBER that we keep everything in supplies, and everything in our place in its place. We invite inspection. Catalogues of our numerous specialties sent free.

"With EAGLEINE OILS and SOLARINE METAL POLISH
We Lubricate and Shine where others fail"

PERRIN, SEAMANS & CO.

57 OLIVER STREET, BOSTON, MASS.

TOOLS AND SUPPLIES

FOR

WATER WORKS CONSTRUCTION

Send for Catalogue No. 6.

S. D. M. J.

Members of the Association AND
Subscribers to the Journal

Can help pay the cost of publication by consulting the advertisements when in need of supplies.

ESTABLISHED 1853.

14,000,000 BARRELS

"HOFFMAN"

....CEMENT....

Have been used on important works throughout the United States.

NO OTHER CEMENT COMPANY CAN SHOW SUCH A RECORD.

LAWRENCE CEMENT CO.

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Sales Office, No. 1 Broadway, New York.

S. D. M. J.

E. P. McDONOUGH. HENRY M. CLARK.

Boston Engineers' Supply Co.,

RUBBER HOSE, BELTING AND PACKING,

Oils and Mill Supplies,

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No. 143 Broad Street,

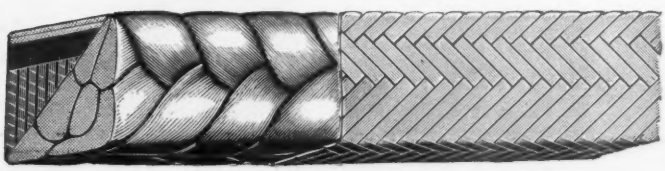
TELEPHONE, BOSTON 3559-2. **BOSTON.**

Handlers of "Highest Grades Cylinder Oils."

M. J. S. D.

"Combination"

HYDRAULIC AND STEAM PACKING



PATENT APPLIED FOR.

An Elastic Sectional Rod and Plunger Packing.

A. W. CHESTERTON & CO.,

64 India Street, Boston.

M. J. S. D.

MEMBERS of the New England Water Works Association, when about to purchase supplies, should always consult the advertising pages of the JOURNAL, and at least allow the advertisers a chance to submit prices. When writing to advertisers always mention this JOURNAL.

Water is not Tainted by this Paint

OFFICE OF
HARRY P. HUMBERT,
CITY CLERK.

KEITHSBURG, ILL.,
October 23rd, 1899.

The National Paint and Varnish Company,
Manufacturers of Graphite Paints and Varnishes,
Cleveland, Ohio.

GENTLEMEN:

Your letter of the 8th is at hand, acknowledging receipt of the money sent you in payment for the paint purchased of your agent, that we painted our Stand Pipe with. Will say that we painted the stand pipe inside and out with your paint. So far it has given very excellent satisfaction. It has the body, together with the staying qualities, and to any one needing a paint for iron or steel, must say that they could not do better than to purchase your paint. In conclusion, will say that we have not had one complaint from the water being tainted by the paint since the water was turned on after finishing the painting, and we did not give it much time after the paint was put on. Hoping that you will have good success with your paints, as you deserve it, we remain,

Yours truly,
Approved: TOM A. MARSHALL,
Mayor.
Attest:
HARRY P. HUMBERT,
City Clerk, and Supt. Water Works.

S. D. M. J.

THE GOULD PACKING CO.

Gould's Packing

Trade Mark.

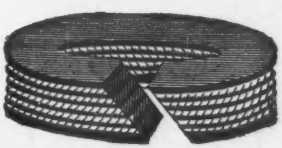
If you want the best, get

Gould's Steam and Water Packing ....

The original ring packing

Buyers will see that our name, Gould's Steam and Water Packing, and our Trade Mark are stamped on every package. *Unless so stamped they are imitations.*

In ordering be careful to give the EXACT diameter of stuffing-box and of piston-rod or valve-stem.



88 Cambridge Street, East Cambridge, Mass.

S. D. M. J.

VENTURI METER

The VENTURI METER is a practical meter for measuring large quantities of water.

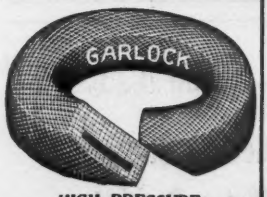
ITS ACCURACY is unquestioned, and it is frequently employed to test the performance of pumps.

NO BY-PASS is necessary, and the cost of tees, elbows, and gate valves is avoided.

BUILDERS IRON FOUNDRY,
Providence, R.I.

.D M. J. S.

Packings that Pack



HIGH PRESSURE

WATERPROOF HYDRAULIC

GARLOCK HIGH PRESSURE RING is made especially for high steam pressures. The rubber cushion is on the **INSIDE,** and can't be damaged by oil or intense heat — the fibrous matter is absolutely **HEAT PROOF.** It positively cannot bake, vulcanize or "burn out"; it must **WEAR** out. It gives from four to six times the service of any other fibrous steam packing.

WE GUARANTEE THAT IT WILL EASILY OUTWEAR ALL OTHERS, OR WILL COST YOU NOTHING

GARLOCK WATERPROOF HYDRAULIC is positively without an equal for cold water. It is used by the U. S. Government on the disappearing gun carriages of all coast fortifications, and against hydraulic pressures of from 1000 to 2500 pounds per square inch. Used by City of New York, Boston, Lowell, Lawrence, and most of the large pumping stations in this country. It will easily outwear any others on cold-water plungers and rods.

OUR OFFER is to make you up a set of either of these, and if not the best you've ever used, we won't charge you a cent. You can be the judge.

CAN'T YOU GIVE US A TRIAL?

THE GARLOCK PACKING CO.

All kinds of Packings and Engineers' Supplies

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New York San Francisco Chicago Philadelphia Denver St. Louis Pittsburgh Cleveland
Palmyra, N. Y. Rome, Ga.

I. S. D. M.

The Journal of the New England Water Works Association

is a quarterly publication, containing the papers read at the meetings, together with verbatim reports of the discussions. Many of the contributions are from writers of the highest standing in their profession. It affords a convenient medium for the interchange of information and experience between the members, who are so widely separated as to find frequent meetings an impossibility. Its success has more than met the expectation of its projectors; there is a large and increasing demand for its issues, and every addition to its subscription list is a material aid in extending its field of usefulness. ALL MEMBERS OF THE ASSOCIATION RECEIVE THE JOURNAL IN PART RETURN FOR THEIR ANNUAL DUES; to all others the subscription is three dollars per annum.

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Or, CHARLES W. SHERMAN,
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Jenkins Pump Valves

FOR HOT WATER SERVICE

FOR COLD WATER SERVICE

OUR Pump Valves for ***cold water and air service*** are equal to our well-known ***hot-water valves.***

For more than a quarter of a century we have tried to make the best ***pump valves*** that could be produced, REGARDLESS OF COST. We leave it to our many thousands of customers to say how far we have succeeded.

Always sold with a ***guarantee*** to give satisfaction on any kind of service required.

When ordering pump valves state diameter, thickness, and size of hole; also for what purpose you desire them.

Pump manufacturers and dealers generally will be glad to furnish you; otherwise, send your orders direct.

PUMP VALVES CAN BE FURNISHED FOR ALL MAKES OF PUMPS AT SHORT NOTICE.

JENKINS BROS.

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